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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 60

GOVERNMENT PUBLICATIONS
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DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON, AND RIVERSIDE CAL., PART II.—LIPPINCOTT.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON AND RIVERSIDE, CAL

PART II

By JOSEPH BARLOW LIPPINCOTT

WASHINGTON

GOVERNMENT PRINTING OFFICE

1902

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DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON, AND RIVERSIDE, CAL.

PART II.

By Joseph Barlow Lippincott.

EAST RIVERSIDE IRRIGATION DISTRICT.

The lands of the East Riverside Irrigation District are 4 miles south of the city of Colton and 4 miles northeast of the city of Riverside. They are divided into approximately equal parts by the boundary line between San Bernardino and Riverside counties, and vary in elevation from about 900 feet to 1,250 feet, being situated on the mesa and bottom lands on the south side of San Bernardino Valley. These lands are specially adapted to the growth of citrus fruits. The district was organized under the Wright irrigation district act, and has had fewer misfortunes than are usual with similar enterprises. It is, however, endeavoring to disorganize. The total area of lands comprised within its boundaries (3,100 acres), 250 acres of which are hilly and rough, being partially unfit for cultivation, leaving 2,850 acres of first-class agricultural land. The irrigation district and its pipe line are shown in Pl. I (Part I). In order to obtain a water supply, in 1892 the irrigation district purchased from Garner & McKenzie 65 acres of artesian lands in the bottoms of Lytle Creek northeast of San Bernardino. Three wells were sunk in these lands, the deepest being 450 feet and the other two about 250 feet each. A cut was also run in the cienaga upon these lands, for the purpose of developing water. The development during that year (1892) produced 100 miners' inches, or 2 second-feet, at a total cost of $5,997. The output of these artesian wells, which are referred to in the description of the wells of San Bernardino Valley, is given in the table on page 36 (Part I).

In 1891 the East Riverside Irrigation District purchased a 24-inch pipe line from Raynor Springs, about 1¾ miles below the artesian land of the district, in sec. 4, T. 1 S., R. 4 W., situated within the district. This pipe line was constructed in the year 1889 by the Vivienda Water Company, for the purpose of serving the greater portion of what is now the East Riverside irrigation district. The pipe is of riveted

iron, the gage ranging from No. 10 to No. 14 Birmingham standard. The maximum pressure per square inch sustained by the different sizes as the pipe was constructed was: No. 14, 30 pounds; No. 12, 71 pounds; No. 10, 110 pounds. The valley hydraulic grade line is 7 feet to the mile, and the discharging capacity 9 cubic feet per second.

After the consummation of the purchase by the district the pipe line was extended 8,100 feet, to the wells that had previously been sunk. The upper portion of the pipe is of steel, No. 14 gage. The reservoir was constructed on the lands purchased. It is 40 feet by 70 feet on the bottom, has a depth of 5 feet, and is cement lined. Two kinds of pipe were used in the distribution system—riveted steel and vitrified clay. In 1892 it was estimated that distribution by this means would cost $15 an acre.

The following are the amounts expended in the construction, with the value of the assets, the purchase of the 24-inch pipe line being included in both statements, which are taken from the report by F. C. Finkle, engineer for the district in 1892:

Expenditures.

Purchase price of Vivienda pipe line	$100,000.00
Extension, 8,100 feet to Vivienda pipe line	23,642.87
Two lateral pipe lines	2,292.10
Reservoir No. 2 (when completed)	1,210.00
Cost of sinking three artesian wells	4,497.00
Drainage cuts to McKenzie Spring	500.00
Total	132,141.97

Value of assets.

24-inch conduit as extended	$123,642.87
Two lateral pipes	2,292.10
Reservoir No. 2	1,210.00
100 inches (2 cubic feet) of water, at $1,000 per inch	100,000.00
Total	227,144.97

The owners of the Vivienda Water Company claim that the pipe line, which they value at $100,000, actually cost $120,160, divided as follows:

Pipe-line material and laying	$96,000
Trenching and back filling	8,000
Right to suspend line on motor bridge	1,000
Bridge across Santa Fe Railroad cut on Third street	360
Engineering and superintendence	3,400
Three miles of cement ditch, including pipe across Little Terquisquite Arroyo	11,400

The cement ditch lines referred to were also transferred to the irrigation district.

RIVERSIDE-HIGHLAND WATER COMPANY.

The Riverside-Highland Water Company is a corporation organized February 21, 1898, under the laws of California, to furnish water for domestic purposes and the irrigation of the lands of shareholders situated in that portion of the East Riverside irrigation district in Riverside County which is known as Highgrove. The capital stock was $200,000, divided into 5,000 shares of $40 each. The policy of the company is to furnish an abundance of water to irrigate 2,500 acres of land at the rate of 1 miners' inch of water measured under a 4-inch pressure for each 5 acres of land for the growing of citrus orchards. Recently the company, by a vote of its stockholders, reduced its capital stock to $100,000, divided into 2,500 shares, of which a little more than 2,300 shares are subscribed for and more than 50 per cent is paid in.

The company is the owner of 157 acres of artesian water-bearing lands a few miles north of Colton, in San Bernardino County, from which the water is conducted in a long underground cement and iron pipe line to the lands of its stockholders at Highgrove, a distance of a little more than 7 miles. On these water-bearing lands there are a number of deep artesian wells, from five of which all of the water now used by the company, amounting to a little more than 300 miners' inches, is pumped by means of one 22-horsepower gas engine and two 30-horsepower electric motors, the electric current being furnished at a cost of 1½ cents per horsepower per hour by the Redlands Electric Light and Power Company. The pumps used are of the centrifugal type.

The company does not know how much water its lands will furnish, but it believes that it has an abundant supply. It is now furnishing sufficient water to meet all the demands of 1,800 acres of both old and young orchards, and so far no one has hesitated on account of lack of water to plant orchards in the territory covered by the company. The water is delivered to consumers on demand upon the payment of a toll of 10 cents per miners' inch for a twenty-four hours' run. The lands watered by the company are at a higher elevation than those watered by any other company in the Riverside district, hence its name. The orchards watered are relatively free from frost.

The East Riverside Irrigation District still exists, with its board of officers, but is not operating its system, the Riverside-Highland Water Company supplying water to such portion of the lands as the owners have become stockholders in its company, also to other lands. The landowners within the East Riverside irrigation district, after an effort of eight years, found it impracticable to carry on the system under the act of the legislature popularly known as the Wright act, owing to the fact that the act provided that the revenue should be raised by annual taxation, and also to the extreme difficulty experienced in collecting the taxes thus levied, resulting in numerous tax sales

and in suits to restrain the execution of tax deeds by the owner just before the expiration of the redemption period. These suits were expensive to the district, in many instances costing more to defend than the taxes were worth when collected, and resulting in vexatious delays and appeals to the higher court. When no redemption was made from tax sales the tax deeds were executed and delivered to the district, which invariably had to become the purchaser, for no private person would venture to purchase at the sales for fear of expensive litigation to protect the titles procured. In this way a large tract of unimproved land owned by divers and sundry persons, both residents and nonresidents, became conveyed to the district, and while the law authorized the district as owner to sell the lands at their market value, no purchaser could be found who was willing to buy them under the titles held by the district. The lands subject to taxation diminished every year to such an extent that it became manifest that the entire revenue of the district for the payment of its obligations—interest on bonds, operating expenses, etc.—would have to be met by the few landowners who were faithful in paying their taxes; hence the landowners, for self-protection, organized the Riverside-Highland Water Company and ceased to operate as the East Riverside Irrigation District.

LOWER SAN BERNARDINO VALLEY ABOVE RINCON.

Santa Ana River is the most important stream of southern California west of the Coast Range. It includes among its tributaries all of the streams entering San Bernardino Valley, and drains a total area above Rincon of 1,463 square miles, including valley lands, exclusive of the lands tributary to Lake Elsinore; 555 square miles of the basin are mountainous. San Bernardino Valley proper contains 525 square miles.[a] There is a secondary coast range lying along the western edge of the valley, through which Santa Ana River cuts a canyon, beginning at Rincon, which is the railroad station of Crary. These hills are of a shale and sandstone formation of more recent geologic origin than the main range to the east, and constitute a dam or dike which concentrates and throws to the surface most of the underflow or seepage water proceeding through the valley toward the sea. This produces a greater volume of water in the river at Rincon during the irrigation season than at any other place along the stream. During the summer there is a larger body of water flowing at Rincon than at any other place in California south of the Tehachapi Mountains, except in Colorado River.

The streams surrounding San Bernardino Valley have drainage basins which are exceedingly steep and are poorly supplied with forest cover. The basin above Rincon is of granite origin. The storms which occur in southern California are frequently violent, and falling on these drainage basins produce torrential floods which rush onto

[a]For details of these drainage areas see Part I, pages 51 and 52.

the plains, carrying large quantities of granitic detritus. In this way San Bernardino Valley has been built up. These great beds of gravel and bowlders have a high percentage of voids, the porous space being probably one-third of the mass. Consequently the floods which are projected upon the plains are rapidly absorbed, and the great underground reservoir, with a controlling outlet at Rincon, the storage capacity of which is very great, is filled.

If an area of gravel of 500 square miles should be charged to a depth of 300 feet its storage capacity would be 32,000,000 acre-feet of water. These figures are given merely to suggest the enormous capacity of this great underground storage reservoir of San Bernardino Valley. It has been charged with waters through a long cycle of years by the floods described. In addition to the winter floods the summer flow of all the streams from San Antonio Creek to Mill Creek is diverted and used for irrigation purposes, and probably 50 per cent of it sinks into the ground and reenforces the water plane. This large underground reservoir slopes toward Santa Ana River, and its surplus waters are brought to the surface in the canyon at Rincon. The velocity with which the water passes through the gravels is undoubtedly very slow and varies with the density of the soil and the steepness of the slope, causing a very constant delivery of water at the Rincon Narrows.

In June, 1898, a series of measurements was made to determine the relation between the water flowing on the surface of the ground at the mouths of the various mountain basins entering San Bernardino Valley and that returning into the channels of the Santa Ana in the central portions of the valley. The following approximate results were obtained:

Discharge measurements in San Bernardino Valley, 1898.

Stream.	June.	September.[a]
	Second-ft.	*Second-ft.*
Mountain streams above Slover Mountain	80	63
Mountain streams below Slover Mountain	21	17
Total summer streams from mountains	101	80
Return and developed water above Slover Mountain	[b] 138	[b] 145
Return water between Slover Mountain and Riverside Narrows	75	62
Return water between Riverside Narrows and Rincon	61	53
Total return water above Rincon	274	260

[a] Measurements made between August 27 and September 9.
[b] Riverside Water Company's lower canal not included.
NOTE.—One second-foot equals 50 California miners' inches.

From the foregoing table it will be seen that in June, 1898, there were 173 second-feet, or 8,650 miners' inches, and about September 1 180 second-feet more water seeping into the channels of Santa Ana River in the central portion of the valley than there was entering the valley from the mountain drainage basin.[c] The amount of water rising in the central portion of the valley was about three times the amount

[c] For details see page 47, Part I.

that was being furnished from the mountain streams. During the winter season the mountain streams are much larger in volume. In the case of San Gabriel River, in June, 1898, there was a total of 16 second-feet of water entering from mountain drainage basins above Puente, and 62 second-feet were found flowing in The Narrows, where San Gabriel River cuts through the same secondary coast range that the Santa Ana encounters at Rincon. A similar condition exists opposite Tropico, on Los Angeles River, where in June, 1898, there were 68 second-feet of water flowing and no water entering from the surrounding mountain drainage basins.

The amount of water which returns from irrigation into the channel of the Santa Ana below the lands irrigated is known to be large. According to tables which have been prepared by Prof. L. G. Carpenter, in charge of the Colorado experiment station at Fort Collins, Colo., the velocities of underground water are found to be less than 1 mile a year under ordinary conditions. It will therefore require a number of years for return irrigation water which, for instance, is used in the neighborhood of Rialto or Riverside to reach the channel of Santa Ana River. During the summer of 1899 Mr. Cyrus C. Babb, a hydrographer from the United States Geological Survey, made a determination of the amount of water returning from irrigation in the Solomonsville Valley, on Gila River, Arizona, and found that a volume equaling 64 per cent of the amount which was being used for irrigation at that time was returning to the stream; in the neighborhood of Phoenix the amount returning was found, in a similar manner, to be 40 per cent. In Ogden Valley, Utah, on Ogden River, Prof. Samuel Fortier determined, as the result of thirteen measurements made in the summer of 1894, that while the inflow into the valley was 98.9 second-feet the amount used for irrigation was 76.3 second-feet and the outflow was 115.9 second-feet, showing a greater amount returning than was being used at that time for irrigation. This was doubtless due to the fact that greater quantities of water were used for irrigation in the spring than during the summer months. In Colorado, on Cache la Poudre River, Professor Carpenter, as a result of extensive measurements and experiments, has drawn the following general conclusions:

(1) There is a real increase in the volume of the streams as they pass through the irrigated sections.

(2) The inflow is practically the same throughout the year. It is greater in summer and less in winter, principally because of the effect of the temperature on the soil.

(3) The passage of the seepage water through the soil is very slow, so that it may take years for the seepage from the outlying lands to reach the river.

(4) The seepage water is already an important agricultural factor of the State. The capital value of the water thus received in the valley of the Cache la Poudre alone is not less than $300,000, perhaps $500,000, and for the Platte it is from $2,000,000 to $3,000,000. It is large for the other streams, but of unknown amount.

(5) Ultimately the returns from seepage will make the lower portions of such

valleys as the Platte more certain of water and will probably permit a larger acreage to be grown.

(6) The results here shown may be expected to apply, with limitations, to other valleys similarly situated, where irrigation is as copious, crops the same in character, and the subsoil and rock strata similar and at approximately the same inclination. Where the soil is less porous a greater time must elapse for the water to percolate.

At Rincon there is a flat of approximately 4 square miles area immediately above the canyon, which is believed to contain gravel and sand to depths of at least 50 or 60 feet, below which alternate layers of clay and gravel are believed to exist. Approximately one-third of this area lies on the south or left bank of the river and the remaining two-thirds on the north bank.

Numerous measurements have been made from the Riverside Narrows through to Olive, and the maximum volume of water that occurs at any point in the river is believed to be at the wagon-road crossing of the stream near Rincon.

In the following table is given a series of measurements made by the United States Geological Survey approximately 1 mile below the railroad bridge crossing Santa Ana River below Rincon, the measurements having been made at that point until September 29, 1899, since which date they have been made at the wagon bridge. On September 13, 1899, it was found that when there were 74.38 second-feet of water at the Geological Survey gaging station there were 76.61 second-feet of water at the wagon bridge, or 2.23 feet more water at the wagon bridge than at the Geological Survey station. The wagon bridge being the point of maximum flow, subsequent measurements were made there.

Discharge measurements of Santa Ana River and canal near Rincon, below the mouth of Chino Creek.

Date.	Hydrographer.	Discharge of river.	Discharge of canal.	Total discharge.
1898.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
June 21	F. H. Omsted	79.81	3.18	82.99
1899.				
January 3	S. G. Bennett	209.40	2.30	211.70
January 16	F. Rolfe	231.90	0.00	231.90
January 28	do	216.00	6.50	222.50
February 15	do	181.00	1.75	182.75
March 4	do	108.60	0.00	108.60
March 18	do	199.89	0.00	199.89
April 6	do	172.23	0.00	172.23
April 18	do	101.10	2.75	103.85
May 2	do	100.34	2.45	102.79
May 15	do	100.36	3.95	104.31
June 3	do	110.27	3.18	113.45
June 16	S. G. Bennett	87.89	1.65	89.54
July 4	F. Rolfe	68.89	2.42	71.31
July 18	do	64.13	1.54	65.67
August 1	do	57.82	3.44	61.26
August 15	do	64.71	3.16	67.87
August 30	S. G. Bennett	65.90	2.00	67.90
September 13	J. B. Lippincott	72.73	1.65	74.38
September 29	F. Rolfe	83.82	0.00	83.82

Discharge measurements of Santa Ana River at wagon bridge above the mouth of Chino Creek.

Date.	Hydrographer.	River.	Chino Creek.	Springs.	Total discharge.
1899.		*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
October 25	J. B. Lippincott	131.32	14.52	0.50	146.34
October 26	do	146.53	14.52	0.50	161.55

Discharge measurements of Santa Ana River at Riverside Narrows, below all Riverside diversions and north of Arlington Heights.

Date.	Hydrographer.	Discharge.
1898.		*Sec.-ft.*
June 20	F. H. Olmsted	47.63
August 29	do	39.05
1899.		
July 17	F. Rolfe	31.70
September 12	J. B. Lippincott	39.69

For the purpose of comparison four measurements of the amounts of water flowing at Rincon and at the division box of the Santa Ana and Anaheim irrigation companies were made on the same dates, with the results shown in the following table:

Discharge measurements of Santa Ana River.

Date.	Hydrographer.	U. S. G. S. gaging station below Rincon.	Division box of Santa Ana and Anaheim irrigation companies.
1898.		*Sec.-ft.*	*Sec.-ft.*
June 21	F. H. Olmsted	79.81	67.47
1899.			
August 30	S. G. Bennett	65.90	59.62
September 13	J. B. Lippincott	72.73	71.68
October 25	do	[a] 146.34	144.72
Total discharge		364.78	343.49

[a] Measured at Rincon wagon bridge.

At the time of the first three measurements there was flowing in a ditch on the left bank of the river opposite the gaging station 3.18, 2, and 1.65 second-feet of water, respectively, which is not included in the totals given in the foregoing table. If included it would show a still greater quantity of water at Rincon. The average of the measurements indicates the presence of 5.32 second-feet (266 miners' inches) more water at Rincon than at the division box. If the greater amount of water found at the Rincon wagon bridge, as compared with that at the original gaging station, is considered, as well as the diversions of the ditch on the left bank opposite the original gaging station, then it is shown by these measurements that there is

a loss of fully 8 second-feet between the Rincon wagon bridge and the division box of the Santa Ana and Anaheim water companies. On September 13, 1899, there were at the Rincon bridge 76.61 second-feet of water, while in the two canals of the Santa Ana and Anaheim companies, at a point opposite Esperanza Siding and above all irrigation from either canal, there were only 58.68 second-feet of water, showing a loss of 17.93 second-feet (896 miners' inches) between those points. On October 26, 1899, there were 161.55 second-feet of water at the Rincon bridge and 122.37 second-feet in the canals and river opposite Esperanza, the total amount in the canals being 73.21 second-feet. This shows a loss of 39.18 second-feet (1,959 miners' inches). These measurements are not given as absolute, but they were the best possible determinations under existing conditions. The fact that a loss is shown by each of the observers mentioned is considered evidence that a loss exists and that it is large. Additional measurements are desirable in order to determine more definitely the amount of this loss.

An examination of the wells in the vicinity of Rincon was made in connection with the investigation. As a result it is believed that a bed of gravel, cobble, and sand 40 feet deep exists on the south side of the river, that it is porous and filled with water, and that development works of proper size and form could obtain from it a large supply. From the Auburndale bridge to the Rincon bridge the river gains 12.75 second-feet of water, as indicated by the measurements of September, 1899, Chino Creek not being considered. An examination of the records of wells north of the river indicates that a blanket of clay slopes from the neighborhood of Chino toward the south. Artesian wells occur in the neighborhood of Chino, and flowing water is obtained as far south as the Pioneer schoolhouse, which is approximately 3 miles north of the land referred to. In a well on the property of Mr. Durkee, approximately 1 mile north of this land, a blanket of hard clay 20 feet thick was encountered at a depth of 47.5 feet from the surface of the ground. Beneath this was coarse gravel. The water in this well rose to within a few feet of the surface of the ground. The well furnishes a supply which has never been exhausted by the demands upon it.

Mr. Durkee states that similar conditions were encountered at the schoolhouse well. From the Auburndale bridge to Chino Creek springs are found on both sides of the valley. The evidence obtained from the wells indicates that a blanket of clay may be found in the gravel beds near Rincon. If this layer of clay exists, beneath it will be found large bodies of water, which can be pumped extensively if they do not flow naturally, and the water supply be increased thereby. The only evidence to the contrary that was found was at the pipe works, approximately 3 miles southeast of Rincon, where indefinite information was obtained that two wells have been put down, one 500

and the other 600 feet in depth, through sandstone, bowlders, and gravel, without encountering a layer of clay. The water in these wells, however, rose to within 25 feet of the surface, and the supply has been found sufficient to meet all demands upon it. The elevation of these wells at the surface of the ground is approximately 100 feet above the river at Rincon. At the foot of the small mesa which immediately joins the town on the south shallow wells have been put down to a depth of 25 or more feet, from which flowing water has been obtained.

If development works can be located which will permit the lowering of the water plane 21 feet beneath the surface of the ground, where it now stands, over an area of 1,000 acres, sufficient water could be obtained to furnish 1,000 miners' inches for a period of six months. It has previously been shown that there enters the river naturally from the eastern end of the valley to the Rincon bridge, inclusive of Chino Creek, approximately 700 miners' inches. This increase indicates a supply which is constantly approaching these lands and which should be an addition to the storage capacity of the gravel mentioned. It is believed, therefore, that from 1,500 to 2,000 miners' inches of water could be obtained if development works were constructed which would permit the lowering of this water plane each season 21 feet over an area of 1,000 acres. In a gravel bed west of Burbank the West Los Angeles Water Company has constructed a cut approximately 3,000 feet in length, which varies in depth from nothing to about 25 feet, and which is now delivering, at the end of the drought of 1900, in the neighborhood of 300 miners' inches of water in a locality which is not so favorably situated for the purposes of developing water as are the lands referred to. The works of the West Los Angeles Water Company consist of an open cut in which is placed a wooden flume with sides and top but without bottom. The water enters the flume principally through the bottom. These development works have been in operation since the fall of 1895 and have maintained a continuous discharge of water, although the water plane of San Fernando Valley has been steadily falling.

The Crystal Springs Water Company has laid approximately 2,000 feet of sewer pipe, with open joints, in the sandy bed of Los Angeles River in the narrows west of Verdugo. There are four pipes, laid in two cuts, which are collecting from 400 to 500 miners' inches of water from the river bottoms.

Broadly speaking, the method of procedure should be to divert the entire flow of Santa Ana River near the Auburndale bridge at the beginning of the irrigation season, say the first of May, and carry it in a lined conduit to a point west of Rincon where a drop could be obtained which would produce a substantial water power. The water stored in the gravel beds should then be drawn down by means of pumps operated by this power. At the end of the irrigation season

the pumps could be stopped and the water be returned to the natural bed of the river between the Auburndale bridge and Rincon during the season of the year when the supply is large and when the loss to the river in recharging these beds, in addition to the natural inflow of water returning from irrigation, would not be felt. In this manner the storage capacity of the gravel beds would be available the following spring, when the water plane could again be drawn down. Any artesian water that might be found would be in addition to the water obtained from the pumps.

Summarizing, the following conclusions have been reached:

(1) That a large percentage of water used for irrigation returns to the channels of the streams, the amount being greater where the soil is porous and the slopes are steep, both of which conditions exist in San Bernardino Valley.

(2) That the movement of the water through the soil is exceedingly slow, and that while the increase due to irrigation is now felt at Rincon the volume of return water from irrigation will increase in the future and will be a permanent source of supply.

(3) Water of this character is now making its appearance on the lands near Rincon. This is indicated by the fact that although we are now practically at the end of a nine-years' drought the water plane of these lands has steadily risen, until orchards, vineyards, and alfalfa fields which are said to have previously flourished have been drowned. Around Riverside alone 5,000 miners' inches (100 second-feet) of water are now being used for irrigation.

(4) It is impossible to determine accurately the amount of water that could be gathered. It is believed, however, that about 2,000 miners' inches or more could be obtained by pumping. This amount would be independent of any supply which would be obtained from artesian wells.

(5) That the stream measurements show a loss between Rincon and the head of the Santa Ana canal near Esperanza of about 800 miners' inches, which might be saved by a lined conduit extending down the canyon about 7.4 miles.

WELLS IN REDLANDS AND SAN BERNARDINO QUADRANGLES.

All of the wells in the Redlands and San Bernardino quadrangles, irrespective of size or producing capacity, were visited by representatives of the Geological Survey during the summer of 1900. There were 412 wells in the Redlands quadrangle, which were inspected by Mr. Louis Mesmer, of Los Angeles, and 478 wells in the San Bernardino quadrangle, which were inspected by Mr. C. J. Roney, of the same city. The results of the observations were described with considerable detail in the field record books, but have been condensed for publication in this report and are given in the following tables. The

numbers of the wells in the tables correspond with those on the map (Pl. I, Part I) and are the same as those given to the detailed descriptions in the field record books. The principal facts are stated in abbreviated form. In the first column is the number of the well as shown on the map. In the next column is the name of the owner, and following that the location, by township, range, and section, the date completed, and the class of well, the latter being indicated by established symbol, *D* meaning dug well, *Dr* driven well, *B* bored well, and *H* horizontal well or tunnel, the accompanying figures giving the size in feet and inches. The elevation of the surface of the well, the elevation of water in the well, and the depth of the well in feet are given in the next columns. The character of the strata is indicated by initials, *C* meaning clay, *G* gravel, *B* bowlders, *L* loam, *S* sand, *R* rock, and *Hp* hardpan. To illustrate: *LSG* is equivalent to loam, sand, and gravel. The next column gives the quality of water, whether hard, soft, alkaline, or sulphurous. The next one gives the method by which the water is obtained, the word *hand* meaning hand pump, *horse* a horsepower machine, *electric* an electric motor, *centrifugal* a centrifugal pump, *gas* a gasoline engine, *wind* a windmill, etc. In the case of the windmill the accompanying figures give the diameter of the windmill in feet. For example: *14 wind* is intended to imply that water is pumped by a 14-foot windmill. In the case of the gasoline engines, electric motors, etc., the accompanying figures indicate the horsepower. The cost of the well and of the machinery (the latter is only roughly approximate) is given in the next two columns, and after that the quantity of water, usually in second-feet, but where otherwise *good* indicates a good supply and *small* a small or deficient supply. In many instances, particularly with capped artesian wells connected directly with pipe systems, it was difficult to determine the volume of water that the well was discharging. In a few instances, which are indicated, the volumes given are for other years than 1900. In the column headed "use of water" the abbreviation *dom* implies domestic use, *st* implies use for watering cattle and horses, and *irr* that water is used for irrigation. Topographic maps were used in determining the elevation of the ground at the well, and the depth to water having been measured with a tape the elevation of the water plane was determined accordingly. The elevations all refer to the summer of 1900, and undoubtedly will vary substantially, either owing to the excessive pumping of water or to subsequent wet years.

Wells in Redlands quadrangle.

No. of well.	Owner	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.		W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
1	Dr. Meeker	1	2	16	1900	D, 4 by 6 feet	1,995	1,718	180	CG			$1,100			
2	Ward, Mills & Co	1	2	21	1900	D, 4 by 6 feet	2,005	1,933	125	CG		Gas	750			
3	Crafton Water Co	1	1	7	1900	D, 5 by 6 feet	3,010	2,992	132	BG		Centrifugal; electric	2,000	$2,500	1.38	Irr; power.
4	do	1	1	8	1900	D, 5½ by 6½ feet	3,650	3,648	93	GR		do	[a] 6,000	2,500	2.70	Irr; power.
5	Mrs. M. A. Brown	1	2	22	1879	D, 4 by 4 feet	2,250	2,225	27	Gravel	Hard	Wind		100		Dom.
6	Geo. McIntosh	1	2	22	1899	D, 4 by 4 feet	2,230	2,189	70	Gravel		Centrifugal; electric				Irr.
7	R. P. McIntosh	1	2	20	1900	D, 4½ by 4½ feet	1,910	1,818	103	SGB	Soft	Cylinder pump; gas	700	925	0.14	Irr.
8	L. Lodge	1	2	16	1900	D, 4 by 6 feet	2,060	2,050	70		do	do		1,500	0.30	Irr.
9	L. Lyons	1	2	16	1900	D, 4 by 6 feet	2,075	2,052		GB		do				Irr.
10	T. P. Christian	1	2	17	1900	D, 4 by 6 feet	1,900	1,748	180	CBSG	Soft	do		1,500		Irr.
11	F. Wieder	1	2	29	1900	D, 4 by 5 feet	1,830	1,779	100	GBC	do	do	450	950		Irr.
12	E. J. Roberts	1	2	28	([b])	D, 4 by 6 feet	2,200	2,192				Horse	300			Irr.
13	H. H. Garstin	1	2	29	1900	B, 10 inches	2,000	1,905	241	CG	Soft	Cylinder pump; gas	800	1,430	0.06	Irr.
14	W. J. Tench	1	2	19		D, 4 by 6 feet	1,720	1,560	163	SGB						Irr; dom
15	East Redlands Water Co.	1	3	36	1900	B, 12 inches	1,805	1,621	514			Cylinder pump; gas	2,200		0.32	Irr.
16	E. & D. Conkling	1	2	31	1899	B, 10 inches	1,795	1,545	350		Hard	do		2,200	0.40	Irr.
17	M. S. Crosswell	1	3	24		D, 4 by 6 feet	1,540	1,378	163	Gravel	Soft	do			0.12	Irr.
18		1	2	33		D, 2½ by 4 feet	2,120	2,060	60							
19	Mr. Gregory	1	2	33	1892	D	2,130	2,123	10			Hand	20			Dom.
20	Dunlap estate	2	2	4	1899	B, 10 inches	2,040	2,040				Centrifugal; gas			0.50	Irr.
21	do	2	2	4	1895	B, 7 inches	2,075	2,077	142			Artesian			0.005	Dom.
22	do	2	2	4	1900	B, 10 inches	2,100	2,100	800	CGS	Hard	do	2,950		0.015	Irr.
23	do	2	2	4	1900	B, 10 inches	2,090	2,090		CSG	do	do				Irr.
24	Houghton & McNee	2	2	4	1895	D, 3 by 4 feet	2,270	2,227	43	Gravel		Wind				Dom.
25	Geo. Clyde (tunnel)	1	2	26		H, 4 by 6 feet	2,700	2,700	97	Porphyry		Gravity	[c] 300		0.02	Irr; dom.
26	Mr. Biggin	1	2	34	1899	D, 6 by 6 feet	2,224	2,163	65	SG					0.16	
27	South Mountain Water Co.	1	2	33	1900	B, 10 inches	2,160	2,132	800+			Centrifugal; steam				Irr.
28	Garland estate	1	3	25	1900	B, 10 inches	1,570	1,394		CG		Cylinder pump; gas				Irr.
29	C. D. Fowler	1	3	5	1891	B, 10 inches	1,180	1,125	70	SG	Hard					
30	West Redlands Water Co.	1	3	35	1899	B, 12 inches	1,600	1,530	226	GCB	do	Cylinder pump; gas	1,250	2,500	0.40	Irr.
31	do	1	3	35	1899	B, 10 inches	1,620	1,529	248	GCB			1,080			Irr.
32	do	1	3	35	1899	B, 12 inches	1,626	1,536	243	GCS		Cylinder pump; gas	1,700	2,500	0.36	Irr.
33	Redlands Heights Water Co.	2	3	1	1900	B, 10 inches	1,880		300	CSG			1,200			Irr.
34	Mr. Painter (?)	2	2	8	1899	D, 4 by 6 feet	1,975	1,932	60	Gravel						
35	do	2	2	8	1899	D, 4 by 6 feet	1,975	1,932	46	Gravel						

[a] Well and tunnel 250 feet long.

[b] Not completed.

[c] Tunnel 97 feet long.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
36	Mrs. Diaz	2	3	14		B, 7 inches	1,545	1,456	96			Hand	$125	$20		Dom.
37	C. W. Blue	2	3	14	1898	B, 7 inches	1,523	1,455	110	Gravel	Hard	Wind	200	75		Dom; irr.
38	A. Gregory	1	3	27	1895	B, 7 inches	1,379	1,274	168	CRGS	do	do	250	500	0.016	Dom.
39	W. McConkey	1	3	27	1898	B, 7 inches	1,380					do				Dom.
40	D. Madell	1	3	27	1898	B, 7 inches	1,377	1,277	171		Hard	do	274		0.001	Dom.
41	G. H. Garland	1	3	26	1899	B, 10 inches	1,450	1,261	246	GC		Cylinder pump; gas		3,000	0.40	Irr.
42	C. L. Hayes	1	3	27	1899	B, 10 inches	1,420	1,270	428	CGSB	Soft	do	850	1,400	0.30	Irr.
43	O. W. Harris	1	3	34	1895	B, 7 inches	1,503	1,303	312	CSG	Hard	Cylinder pump; electric.	600	800	0.075	Irr; dom.
44	Horace Evans	1	3	33	1899	B, 10 inches	1,455	1,259	660	CG	Soft	Cylinder pump; gas	1,900	1,400	0.18	Irr; dom.
45	A. C. Fowler	1	3	32	1898	B, 9 inches	1,250	1,140	170	SGC	do	do	250	300	0.10	Irr.
46	L. C. Smith	1	3	32	1898	D, 3 by 3 feet	1,215	1,135	83	Gravel	Hard	Wind	90	65	0.003	Dom.
47	P. B. Fussell	1	3	32	1897	B, 12 inches	1,253	1,195	165	SGC	Soft	do	330	230		Irr; dom.
48	E. Vaché	1	3	32	1885	B, 7 inches	1,260	1,200	140		Hard	do	176	75		Dom.
49		2	3	4	1893	B, 7 inches	1,350	1,290	150			do				St.
50	W. D. Covington	2	3	4	1893	B, 7 inches	1,325	1,290	157		Hard	Hand	350	20	Small.	St.
51	do	2	3	4	1893	B, 10 inches	1,300	1,300	750		do	Artesian	2,000		0.002	Dom; st.
52	D. S. Jordon	2	3	4	1899	B, 7 inches	1,395	1,379	56	LSGC	do	Wind	80	90	0.001	Dom; irr.
53	Redlands Domestic Water Co.	1	3	35	1899	B, 10 inches	1,560	1,503		CSG	do	Centrifugal; electric	1,800		0.80	Dom; irr.
54	Wood, Bill & Davis	1	3	33	1899	B, 10 inches	1,305	1,225	462	CGS	Soft	Cylinder pump; gas	1,200	1,800	0.40	Dom; irr.
55	D. H. Gillan	1	3	32	1899	B, 8 inches	1,245	1,157	438		do	Air compressor; gas		3,000	0.50	Dom; irr.
56	H. Bermudas	1	3	32	1893	B, 7 inches	1,210	1,156	112		Hard	Hand		3		Dom.
57	N. B. Hinckley estate	1	3	32		B, 10 inches	1,177	1,021	700+			Wind				Dom; irr.
58	Wm. Curtis	1	3	30	1885	B, 10 inches	1,144	1,076	76		Hard	do	150	100	0.002	Dom.
59	E. C. Curtis	1	3	29	1895	B, 7 inches	1,120	1,070	96		do	do	160	75	0.002	Dom.
60	R. T. Curtis	1	3	29	1895	B, 7 inches	1,123	1,073	86	GC	do	do	140	100	0.003	Dom.
61	W. M. Curtis	1	3	29	1899	B, 12 inches	1,125	1,079	415	CG	Soft	Cylinder pump; gas	900	1,800	0.70	Irr.
62	N. B. Curtis	1	3	29	1895	B, 7 inches	1,126	1,076	84		Hard	Wind	140	60	0.001	Dom.
63	N. B. Hinckley estate	1	3	30	1899	B, 36 inches B, 11 inches	1,150	1,103	65 271	Gravel	do	Centrifugal; gas	900	800	0.42	Irr.
64	L. & M. Frink	1	3	30	1889	B, 7 inches	1,140	1,112	62	LSGC	do	Wind	100	163		Dom.
65	Mrs. P. S. Stewart	1	3	30	1898	B, 7 inches	1,144	1,109	76	CG	do	do	150	65	0.001	Dom.
66	Gansnor & Renwick	1	3	30	1898	B, 7 inches	1,140	1,110	200		Soft	do	320	90	0.003	Dom; irr.
67	Redlands Water Co.	1	3	35	1899	B, 10 inches	1,563				Hard	Centrifugal; electric				Irr.
68	Mrs. M. Robison	1	3	30	1870	D, 3 feet	1,110		24		do	Hand			Dry.	
69	Southern Pacific R. R. Co.	1	3	31	1890	B, 7 inches	1,176	1,116	75		do	do	145	20		Dom.
						B, 10 inches		1,208	294	LCG	Soft	Cylinder pump; gas	1,000	935	0.14	Dom; irr

71	do	1	3	31	1898	B, 14 inches B, 10 inches	1,150	1,108	276 84	Gravel	do	Force pump; gas	1,020		0.80	Irr.
72	Owen Buchanan	1	3	31	1898	B, 7 inches	1,265	1,149	237	LSGC	do	Cylinder pump; gas.	379	800	0.14	Irr.
73	W. J. Lawrence	1	3	31	1898	B, 7 inches	1,230	1,143	190	LCG	do	do	304	700	0.12	Irr.
74	Frink Bros	1	3	30	1899	B, 36 inches B, 10 inches	1,147	1,105	335		Hard	Centrifugal; gas	800	700	0.62	Irr.
75	Rhoda Wilson	1	3	30	1899	B, 7 inches	1,138		59	CG	do	Wind	95	65	0.001	Dom.
76	D. Van Leuven	1	3	30	1900	B, 9 inches	1,132	1,098	63		do	Hand	65	14		Dom.
77	E. Hankins	1	3	28	1899	B, 12 inches	1,254	1,200	290	Gravel	do	Cylinder pump; gas.	800	1,300	0.40	Irr; dom.
78	J. A. Osborn	1	3	28	1899	B, 10 inches	1,225	1,173	320	LGC	do	Centrifugal; gas	880		0.50	Irr; dom.
79	do	1	3	28		B, 7 inches	1,224	1,174	190	LGC	do	Wind	300	72	0.001	Dom.
80	Mrs. S. W. Sylvera	1	3	29	1891	B, 7 inches	1,200	1,170	90			do		80	0.001	Dom.
81	A. B. Cook	1	3	29	1897	B, 10 inches	1,206	1,166	110	LSG	Soft	Centrifugal; gas	220	800	0.40	Dom; irr.
82	S. Mansfield	1	3	29	1900	B, 10 inches	1,195	1,163	340	Gravel						
83	do	1	3	29	1890	B, 7 inches	1,193	1,154	109		Hard	Wind	175		Small.	Dom; irr.
84	A. Lenanon	1	3	29	1895	B, 7 inches	1,186	1,156	130		do	Cylinder pump; horse	208	40		Dom.
85	John Furney	1	3	29	1890	B, 7 inches	1,179	1,139	60		do	Wind	100	150	0.003	Dom; irr.
86	Barton Land and Water Co.	1	3	29	1891	B, 7 inches	1,180	1,137	63		do	Hand	100			Dom.
87	M. D. Easton	1	3	29	1890	B, 7 inches	1,121	1,101	45		Soft	Wind	80	70	0.003	Dom.
88	Barton Land and Water Co.	1	3	29	1891	B, 7 inches	1,130	1,100	48		Hard	Hand				Dom.
89	J. R. Campbell	1	3	29	1893	B, 7 inches	1,190	1,155	103		do	do	190	25		Dom.
90	Carl Furst	1	3	29	1891	B, 5½ inches	1,215	1,180	114		do	do	165	35		Dom.
91	S. E. Rockwell	1	3	29	1900	B, 10 inches	1,200	1,170	356	SGR	Soft	Cylinder pump; gas.	1,000	860	0.34	Irr.
92	J. Hickey	1	3	29	1898	B, 9½ inches	1,226	1,190	152	GC	do	do	314	700	0.20	Irr; dom.
93	B. M. James	1	3	29	1899	B, 10 inches	1,230	1,198	220	LSGC	do	do	418	900	0.34	Irr; dom.
94	W. A. Nichols	1	3	28	1891	B, 7 inches	1,246	1,194	122			Hand				Dom.
95	do	1	3	28		B, 10 inches	1,255	1,206	284	GCSR		Cylinder pump; gas.	530	1,000	0.36	Irr.
96	W. D. Tobey	1	3	29		B, 10 inches	1,204		324			do				Irr.
97	S. A. Grover	1	3	28	1899	B, 10 inches	1,253	1,183	231	SC	Hard	do	700	1,100	0.40	Dom; irr.
98	Schee Bros	1	3	28	1899	B, 10 inches	1,280	1,210	425	Gravel	Soft	do	1,400	1,500	0.50	Dom; irr.
99	W. F. Schee	1	3	28	1894	B, 7 inches	1,291				do	do				Irr.
100	Redlands Water Co.	1	3	35	1899	B, 10 inches	1,565				Hard	Centrifugal; steam			1.56	Irr.
101	Barton Land and Water Co.	1	3	28	1900	B, 10 inches	1,315	1,225	250							
102	Willis Miller	1	3	21	1893	B, 7 inches	1,290	1,203	123	SG	Hard	Wind	200	125	0.002	Dom.
103	S. A. Grover	1	3	21	1890	B, 7 inches	1,294				do	do				Dom; irr.
104	C. Cutting	1	3	21	1894	B, 7 inches	1,320	1,220	170		Soft	Cylinder pump; gas.	337	340		Dom; irr.
105	Myron Sherman	1	3	27	1892	B, 8 inches	1,331	1,221	145		do	Cylinder pump; electric.	450	300		Dom; irr.
106	J. S. Hale	1	3	21	1897	B, 11 inches	1,272	1,202	295	Gravel	Hard	Cylinder pump; gas.	600	1,300	0.48	Irr.
107	do	1	3	21	1890	B, 7 inches	1,265	1,201	105		do	Wind	159	200	0.002	Dom; irr.
108	do	1	3	17	1896	B, 10 inches	1,220	1,164	86		do	do	160	75	0.015	Irr.
109	C. A. Shaw	1	3	21	1893	B, 7 inches	1,267	1,217	96		Soft	do	138	87	0.005	Dom; irr.
110	Lewis Deck	1	3	21	1895	B, 7 inches	1,278	1,213	220	GC	do	Cylinder pump; gas.	363	678	0.15	Dom; irr.
110a	do	1	3	21	1895	B, 7 inches	1,278	1,213	150	GC	do				0.15	Dom; irr.
111	I. E. Shaw	1	3	21	1890	B, 7 inches	1,247	1,197	90		do	Hand	150	25		Dom.
112	Alise Van A. Lea	1	3	21	1898	B (2)	1,253		70 130	SLC	Hard	Cylinder pump; gas.	500	700		Not used.
113	A. Gregory	1	3	21	1890	B, 7 inches	1,245	1,194	100		Soft	Wind				Dom.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
114	Gladysta Land and Water Co.	1	3	20	1899	B, 11 inches	1,240					Cylinder pump; gas				Irr.
115	Frank Hess	1	3	21	1897	B, 11 inches	1,243	1,188	163		Soft	Centrifugal; gas	$326	$800	0.24	Dom; irr.
116	C. S. Lombard	1	3	16	1897	B, 10 inches	1,246	1,182	180		Hard	Cylinder pump; gas			0.30	Dom; irr.
117	S. Ronzone	1	3	16	1899	B, 9 inches	1,257	1,192	98	LSG	do	Wind	235	200	0.014	Dom; irr.
118	Thos. Blakeley	1	3	16		B	1,254				do	Electric				Irr.
119	Elza Boger	1	3	16	1899	D, 4 by 4 feet B, 9 inches	1,255	1,185	132	(a)						
120	M. R. Gay	1	3	17	1896	B, 11 inches (2)	1,220	1,170	105	SGC	Hard	Air compressor; electric.	200		0.22	Irr.
121	W. W. Story	1	3	16	1900	B, 10 inches	1,262	1,193	163	GC	do	Cylinder pump; gas	400	1,500	0.50	Dom; irr.
122	John Dostal	1	3	15	1897	B, 10 inches	1,403	1,230	174	HpSG	Soft	Wind	348	140	Small.	Dom.
123	J. F. Boyd	1	3	16	1896	B, 10 inches (2)	1,290	1,180	100 110		do	Cylinder pump; gas	500	900	0.20	Irr; dom.
124	Wm. Lindenberg	1	3	20	1893	B, 7 inches	1,220	1,180	93		Hard	Wind	140	150	0.009	Irr; dom.
125	H. S. Drew	1	3	19		B, 14 inches B, 10 inches	1,167	1,133	164 291		Soft	Cylinder pump; gas	1,300	1,500	0.60	Irr; dom.
126	James Smith	1	3	19	1892	B, 7 inches	1,164	1,130	90		Hard	Hand	150	10		Dom.
127	Bryan estate	1	3	20	1900	B, 10 inches B, 8 inches	1,190	1,143	510 118		do	Centrifugal; gas			0.40	Irr.
128	A. M. Ham	1	3	30	1887	B, 7 inches B, 5 inches	1,155	1,120	150 300			Cylinder pump; gas	1,500	900		Dom; irr.
129	P. H. Covington	2	3	10		B, 7 inches	1,440	1,392	58		Hard	Hand				Dom.
130	Clark & Brotherton	1	3	20	1900	B, 10 inches B, 8¼ inches	1,195	1,162		LCG[a]						
131	J. J. Prendergast	1	3	29	1893	B, 10 inches	1,200	1,166	422		Hard	Cylinder pump; gas	1,200	800	0.30	Irr; dom.
132	H. H. Cole	1	3	30	1888	B, 7 inches	1,140	1,108	82	LSG		Wind	140	180	Small.	Irr; dom.
133	H. S. Drew	1	3	19	1886	B, 7 inches	1,138		70		Hard	do	140	150	0.001	Dom.
134	C. M. Baxter	1	3	30	1899	B, 10 inches	1,147	1,116	100			Centrifugal; gas			0.60	Irr.
135	do	1	3	30	1892	B, 7 inches	1,147	1,113	80		Hard	Hand				Dom.
136	C. H. Lehmann	1	3	19	1891	B, 10 inches	1,129	1,103	458		Soft	Cylinder pump; gas	1,300	900	0.40	Irr; dom.
137	A. E. Cole	1	3	30	1892	B, 7 inches	1,125	1,104	100	LSGC	Hard	Wind	160	100	0.005	Irr; dom.
138	A. McCrary	1	3	30	1891	B, 7 inches	1,120	1,093	40	CG	do	Hand	64			Dom.
139	H. R. Scott	1	3	19		B, 7 inches	1,120	1,108	593		do	Centrifugal; gas	1,000	1,000		Irr; dom.
140	do	1	3	19	1879	B, 6 inches	1,127	1,109	500		do					
141	E. H. Durnford	1	4	24	1894	B, 7 inches	1,103	1,093	500		Soft	Centrifugal; gas			0.60	Dom; irr.
142	James Birch	1	4	24	1890	B, 7 inches	1,096	1,087	300		do					Dom.
143	do	1	4	24		B, 7 inches	1,098	1,081	100							
144	D. W. Roach	1	4	24	1899	B, 7 inches	1,102	1,087	85	SG	Hard	Hand	130	24		Dom.
145	E. F. Van Leuven	1	4	25	1890	B, 7 inches	1,103	1,083	48		do	Wind			0.001	Dom.

146	W. H. Van Leuven	1	4	25		B, 7 inches	1,101	1,081	75		do	do				Dom; irr.
147	W. J. Doran	1	3	30	1900	B, 10 inches	1,106	1,086	100		do	do	200			Dom.
148	L. R. Van Leuven	1	3	30	1882	B, 7 inches	1,108	1,093	270		do	do	600	109	0.001	Dom; irr.
149		1	3	30		B, 7 inches	1,120				do	do				Dom; irr.
150	O. Taylor	1	3	32	1897	B, 7 inches	1,210		75		do	do		120	0.003	Dom; irr.
151	H. C. Hamanway	1	3	32		B, 7 inches	1,209				do	Hand				
152	G. J. Grant	1	3	32	1896	B, 7 inches (2)	1,206				do	Gas				Irr; dom.
153	S. L. Gregg	1	3	32		B, 7 inches	1,202				do	Wind				Dom.
154	H. C. Hamanway	1	3	32	1899	B, 10 inches	1,250	1,198	200		do	Cylinder pump; gas			0.32	Irr.
155	T. Morris	1	3	32	1890	B, 7 inches	1,260	1,195	125	LCG	do	Wind			0.002	Irr; dom.
156	S. V. Horton	1	3	32	1891	B, 7 inches	1,270	1,195	125	LCG		do	200	175	0.01	Irr; dom.
157	C. T. Covington	2	3	4	1891	B, 7 inches	1,455	1,415	65	SG	Hard	Hand	100	25		Dom.
158	Mrs. Van Leuven	1	4	25	1896	B, 7 inches	1,105	1,085	78		do	do	150	15		Dom.
159	J. H. Pierson	1	4	24	1884	B, 6 inches	1,104	1,103	605	CG	do	Centrifugal; gas	10,222	1,200	0.60	Dom; irr.
160	F. M. Strang	2	3	10	1897	D, 3 by 3 feet	1,500	1,423	79	SG	do	Hand	77	4		Dom.
161	Railroad School	2	3	10	1891	B, 7 inches	1,527	1,427	118	CG	do	do	180	25		Dom.
162	D. Mulvahill	2	3	10	1891	B, 7 inches	1,470	1,439	61	CG	do	do	115	22		Dom.
163	R. P. Lauretzen	2	3	10		B, 7 inches	1,550	1,474	106		do	do				Dom.
164		2	3	4		B, 7 inches	1,430				do	do				Dom.
165	— DeGarmo	2	3	8		B, 7 inches	1,575	1,485	164		do	Wind				Dom.
166	Smiley Bros	2	3	4		D, 7 by 7 feet	1,347	1,330	23		do	Centrifugal; gas			0.50	Irr.
277	L. F. Cram	1	3	3	1895	B, 12 inches	1,305	1,189	116	SCGR	Soft	Wind	1,000	100	Small.	Dom; irr.
278	C. C. Tyler	1	3	2	1900	D, 4 by 5 feet	1,305			SCGR						
279	John McBride	1	2	6	1900	D, 4 by 4 feet	1,650	1,636	65	SGB		Centrifugal; gas	500	400		Irr; dom.
280	do	1	2	6	1894	H, 4 by 6 feet	1,654	1,654	130	Granite	Hard	Tunnel, 130 ft., flows	250		0.02	Irr.
281	Cram Bros	1	3	2	1899	D, 4 by 4 feet	1,600	1,485	120	CG			300			
		N. W.														
282	E. Highland Orange Co.	1	3	35	1900	B, 12 inches B, 10 inches	1,630	1,610	280 140	SGR		Tunnel, flows	1,680		0.26	Dom; irr.
283	do	1	3	35	1900	D, 4 by 4 feet B, 10 inches	1,680	1,666		SGR						
284	W. M. Bristol	1	3	34	1899	D, 5 by 5 feet	1,650	1,634	50	Gravel	Soft	Cylinder pump; gas		1,250	0.30	Irr.
285	Highland Domestic Water Co.	1	3	27	1899	D, 7 by 9 feet	1,440	1,411	65	GB		2 cylinder pumps; 2 gas engines.		[b]1,500	1.10	Dom.
286	Highland Well Co	1	3	28	1899	D, 8 by 5 feet	1,431	1,415	46			Cylinder pump; gas			0.68	Irr.
		S. W.														
287	J. C. Weeks	1	3	3	1900	D, 4 by 4 feet B, 12 inches	1,295	1,181	([a])		Hard					
288	H. S. Stroven	1	3	3	1898	B, 10 inches	1,253	1,173	165		Soft	Cylinder pump; gas	400	1,160	0.40	Irr; dom.
289	N. Sutherland	1	3	4	1898	Dug B, 12 inches	1,227	1,160	78		Hard					Not used.
290	Pattee & Nye	1	3	5	1900	D, 6 by 8 feet B, 10 inches	1,200	1,150	50 100			Rotary pump; steam			0.60	Irr.
291	G. J. Fowler	1	3	5	1899	D, 5 feet	1,180	1,127	55	SCG	Soft	Hand	50	17		Dom.
292	R. F. Cunningham	1	3	5	1890	D, 6 feet	1,160	1,120	43	Gravel	do	Centrifugal; steam	150	1,450	0.80	Irr.
293	do	1	3	5	1899	B, 7 inches	1,147	1,103	36		do	Hand	160	15		Dom.
		N. W.														
294	do	1	3	31	1900	D, 5 by 5 feet B, 10 inches	1,260	1,226	135 90	CG		Steam			1.04	Irr.

[a] Unfinished.

[b] Two engines.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T.R.S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
295	Redlands Water Co.	1 3 35	1899	B, 10 inches	1,568				Hard					
296	C. K. Matteson	1 3 7	1892	B, 10 inches	1,107	1,083	47	CG	Soft	Centrifugal; steam	$500		0.20	Irr.
297	do	1 3 7	1884	Dug	1,103	1,080	25	SGC	do	Hand	30	$4		Dom.
298	do	1 3 7	1894	B, 10 inches	1,103	1,083	44	SG	do	Centrifugal; gas	175	510	0.60	Irr.
299	Geo. Gustave	1 3 7	1900	D, 4 by 6 feet	1,101	1,082	25	SGR	do	do	50		0.30	Irr; dom.
300	do	1 3 7		D, 3 by 4 feet	1,103	1,085	19	SGB	do					
301	Mrs. H. Taylor	1 3 7		D, 3 feet	1,102	1,080	25	Gravel		Centrifugal; steam				Irr.
302	C. Wiltshire	1 3 6	1895	Dr, 2 inches	1,102	1,080	27		Soft	Hand		25		Dom.
303	Mrs. H. Taylor	1 3 7	1891	B, 3 inches	1,101		235		do	do	300		3.00	Dom; irr.
304	W. F. Somers	1 3 7	1900	B, 10 inches	1,101	1,081	(a)	SGCB						
305	Mrs. Golden	1 4 12	1900	B, 10 inches	1,099	1,099		SGC		Artesian				Irr.
306	do	1 4 12	1898	B, 8 inches	1,102	1,102	744		Soft	do	1,600		[b]1.10	Dom; irr.
307	W. F. Somers	1 3 7	1895	Dug	1,098	1,080	20		do	Hand	20		7.00	Dom.
308	do	1 3 7	1899	D, 3 by 3 feet	1,097	1,079	20		do	do	20		4.00	St.
309	John Kaus	1 3 7	1899	B, 8 inches	1,103	1,085	20			Steam	40			Dom.
310	F. P. Sargent	1 4 13	1894	Dr, 2 inches	1,096	1,084	24	Sand	Hard	Hand	15	10		Dom.
311	S. E. Fitzhugh	1 4 12	1888	B, 3 inches	1,080	1,073	234	SGC	Soft	do	500	6		Dom.
312	do	1 4 12	1885	B, 7 inches	1,081	1,064	20		Hard	do	35	6		Dom.
313	W. Borne	1 3 7		D, 3½ by 3½ feet	1,103					do				Dom.
314	Geo. Covalt	1 3 7	1899	B, 7 inches	1,104	1,079	30		Hard	do		4		Dom.
315	W. F. Somers	1 4 1		B, 3 inches	1,099	1,095	283		Soft	do				Dom.
316	W. K. Bledsoe	1 4 1		D, 4½ feet	1,103	1,086	21	SG	Hard	do	25	3		Dom.
317	T. J. West	1 4 1	1900	D, 5 feet	1,093	1,090	20	SG	Soft	Centrifugal; steam	400	820	1.30	Irr.
318	S. Van Leuven	1 3 6	1883	B, 3 inches	1,104	1,105	309		do	Wind				Irr; dom.
319	Ed. Dailey	1 3 6	1890	B, 3 inches	1,102	1,091	325		do	Hand				Dom.
320	do	1 3 6	1890	B, 3 inches	1,106	1,105	320		do					Not used.
321	do	1 3 6	1885	B, 3 inches	1,103	1,093	350		do	Hand				Dom.
322	W. A. Brouse	1 3 6	1899	Dug	1,104	1,084	22	SG	do	do	25	5		Dom.
323	do	1 3 6	1884	D, 5 feet	1,104	1,084	26	SG	do	Centrifugal; steam	150	630	0.50	Irr.
324	do	1 3 6	1893	D, 5 feet	1,106	1,086	25		do	do	150	620	0.50	Irr.
325	Herman Smith	1 3 6	1899	D, 4 by 4 feet	1,109	1,084	27	SG	do	Hand	100	12		Dom.
326	J. Friedmann	1 3 6	1885	D, 6 feet	1,107	1,090	22	SG	do	Centrifugal; steam	130	485	1.00	Irr; dom.
327	J. Dunlap	1 4 1		B, 3 inches	1,102	1,102	185		Hard	Artesian			0.18	Dom.
328	H. C. Keller	1 4 1	1880	B, 2 inches	1,104	1,104	169		Soft	do			0.02	Dom.
329	A. Roberts	1 3 6	1892	B, 3 inches	1,105	1,105	231		do	do	426		0.005	Dom.
330	Warm Creek School	1 3 6	1885	B, 2 inches	1,106	1,101	150			Hand	175			Dom.
331	W. L. McKenzie	1 4 1	1875	B, 2 inches	1,105	1,105	320		Soft	Artesian			0.01	Irr; dom
		N. W.												
332	Wm. Shay	1 3 31	1890	B, 3 inches	1,103	1,103	150		do	do	300		0.06	Dom.

		S.	W.													
333	Wm. Clyde	1	3	6	1889	B, 2 inches	1,106	1,106	146		Soft	Artesian	150		0.03	Irr; dom.
334	Riverside Water Co.	1	4	1	1898	B, 10 inches	1,086		648	CGS	Hard	do				Irr.
335	do	1	4	1	1898	B, 10 inches	1,088		590	SGC	do	do	1,100		1.20	Irr.
336	do	1	4	1	1898	Bored	1,085		384	SCG	do	do				Irr.
337	do	1	4	1		Bored	1,084	1,084	440		do	do				Irr.
338	Redlands Dom. W. Co	1	3	35	1899	B, 10 inches (2)	1,640	1,550	243 400	CSG	do	Centrifugal; electric	650		0.80	Dom.
		N.	W.													
339	Thomas Shay	1	3	31	1888	B, 7 inches	1,103	1,089	20	SGC	Soft	Hand	30	5		Dom.
340	do	1	3	31	1895	D, 4 by 4 feet B, 8 inches	1,098		80		Hard	Cylinder pump; gas.	300	1,680	0.50	Irr.
		S.	W.													
341	R. T. Clyde	1	3	6	1880	B, 2 inches	1,105	1,105	133		Soft	Artesian	100			Dom; irr.
342	F. L. Talmadge	1	3	6	1880	B, 2 inches	1,106	1,106	135		do	Hand	100	5		Dom.
343	Talmadge & Haws	1	3	6	1897	B, 10 inches	1,140	1,132	425	SCBG	do	Centrifugal; gas	850	986	2.00	Irr.
344	Mrs. Haws	1	3	6	1898	B, 2 inches	1,125	1,125	100		do	Hand	75	3		Dom.
		N.	W.													
345	John D. Clark	1	3	31	1899	B, 3 inches	1,130	1,130	125	LCSG	Hard	Artesian	120		0.02	Dom; irr.
346	do	1	3	31	1892	B, 3 inches	1,132	1,132	50	CG	do	do	45			Dom; irr.
347	D. R. Seely	1	3	33	1890	B, 3 inches	1,250	1,176	124		Soft	Wind			0.005	Dom.
348	do	1	3	33	1899	B, 12 inches	1,285	1,110	195			Cylinder pump; gas.				Irr.
		S.	W.													
349	W. D. Stevens	1	3	5	1894	D, 8 feet B, 10 inches	1,180	1,130	40 60		Hard	Centrifugal; gas		815	0.60	Irr; dom.
350	Jane C. Goodman	1	3	6	1894	B, 3 inches	1,140	1,128	284		do	Wind	625	108	0.001	Irr; dom.
351	Jas. Roddick	1	3	5	1898	D, 4 inches	1,143	1,114	30		do	Centrifugal; gas		250	0.20	Irr; dom.
352	Saml. Roddick	1	3	6	1899	Dr, 1½ inches	1,139	1,117	27		do	Hand	7	10		Dom.
353	W. F. Talmadge	1	3	6	1885	B, 7 inches	1,148	1,132	30		do	Wind		80	0.001	Dom; irr.
354	do	1	3	6	1891	B, 3 inches	1,146	1,131	41		do	Hand		6		Dom.
355	A. Downey	1	3	6	1899	Dr, 1½ inches	1,143	1,131	21		Soft	do	4	3		Dom.
356	F. A. Haws	1	3	6	1899	Dr, 1½ inches	1,130	1,120	26		Hard	do	5	5		Dom.
357	E. S. Haws	1	3	6	1899	Dr, 1½ inches	1,130	1,120	20		do	do	5	5		Dom.
358	Mrs. M. C. Haws	1	3	6	1895	B, 3 inches	1,125	1,125	125		Soft	Artesian	250			Dom.
		N.	W.													
359	Walter Shay	1	3	31		B, 7 inches	1,110				Hard	Hand				Dom.
360	Kohl Bros	1	3	32	1890	B, 6 inches	1,147	1,129	60		do	Wind			0.001	Dom.
361	H. D. Rabel	1	3	31	1896	B, 2 inches	1,140	1,140	68		Soft	Artesian	40			Dom.
362	do	1	3	31	1898	B, 3 inches	1,142	1,142	86		do	do	70		0.01	Dom.
363	do	1	3	31	1898	B, 3 inches	1,139	1,139	44		do	do	30		0.25	Dom.
364	do	1	3	31		B, 3 inches	1,137	1,137	72		do	do	70		0.005	Dom.
365	Geo. Miller	1	3	32	1898	B, 6¾ inches	1,130	1,043	92		do	Wind	700	100		Dom.
366	D. J. Carpenter	1	4	24	1900	D, 6 by 9 feet	1,470	1,447	25	CS	Alk					
367	D. J. Carpenter & Co.	1	4	24		B, 7 inches	1,475	1,475	71	SG	do				0.06	Irr.
368	do	1	4	24		B, 7 inches	1,474	1,474	123	SG	do				0.10	Irr.
369	do	1	4	24		B, 7 inches	1,474	1,474	193	SG	do				0.08	Irr.
370	do	1	4	24		B, 7 inches	1,476	1,476	184	SG	do	Centrifugal; gas		1,100	0.14	Irr.
371	do	1	4	24		B, 7 inches	1,473	1,473		SG	do				0.10	Irr.
372	do	1	4	24		B, 7 inches	1,473	1,473	127	SG	do				0.10	Irr.
373	do	1	4	24		B, 7 inches	1,473	1,473	167	SG	do				0.06	Irr.
374	W. J. Linville	1	3	30	1899	B, 10 inches	1,270	1,140	368		Hard	Cylinder pump; gas.		3,000	0.36	Irr.

[a] Not completed.

[b] December, 1898.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location (T. R. S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
375	Mrs. R. L. Burcham	1 3 31	1899	B, 12 inches	1,224	1,154	460		Soft	Cylinder pump; gas.	$1,200	$2,250	0.70	Irr.
376	E. K. Henderson	1 3 30	1899	B, 3 inches	1,233	1,133	134		do	Wind	150			Dom.
377	Jas. McCafferty	1 3 31	1896	B, 7 inches	1,225		80-100		do	Cylinder pump; gas.		2,500	0.40	Irr; dom.
378	J. D. Clark	1 3 31	1897	B, 11 inches	1,170		106	LCB	do	do			0.40	Irr.
379	P. W. Gray	1 3 31	1893	B, 7 inches	1,170	1,120	139		Hard	Wind			0.03	Dom; irr.
380		1 3 30	1900	B, 7 inches	1,310		320	SCGB						
381	John Lin Foster	1 3 32	1894	B, 10 inches	1,220		95		Soft	Wind	600	(a)	0.003	Dom; irr.
382	P. H. Gleason	1 3 32	1900	D, 4 by 4 feet	1,250	1,175	78		do	do			0.002	Dom; irr.
383	E. L. Cumbl	1 3 32	1897	D, 4 by 4 feet	1,128	1,091	38	CSB	Hard	Hand	50			Dom.
384	A. C. Pierce	1 3 32	1898	D, 4 by 4 feet	1,210	1,150	62	LSGB	Soft	Wind	120	140	0.005	Dom; irr.
385	Kohl Bros	1 3 32	1898	B, 10 inches	1,148	1,136	300	SGB	do	Centrifugal; gas	600	700	1.60	Dom; irr.
		S. W.												
386	State of California Hospital for Insane.	1 3 5		B, 10 inches	1,110	1,078	85		Hard	Centrifugal; steam			1.60	Irr.
		N. W.												
387	Geo. Fowler	1 3 32	1888	D, 3 by 3 feet	1,165	1,137	29	CG	Soft	Hand				Dom.
		S. W.												
388	C. D. Fowler	1 3 5	1895	D, 4 feet	1,168	1,135	34	CSGB	Hard	do				Dom.
		N. W.												
389	J. Bagwell	1 3 32	1900	D, 4 by 4 feet; B, 12 inches	1,230	1,117	153		do	Cylinder pump; gas.			0.20	Irr.
390	A. A. Boyd	1 3 32	1895	Dug; B, 7 inches	1,290	1,138	202		do	do			0.22	Irr; dom.
391	Gage Canal Co	1 4 13	1891	B, 10 inches	1,058	1,058	168		do	Artesian			[b] 4.306	Irr.
392	do	1 4 13	1891	B, 10 inches	1,059	1,059	166		do	do			[b] 1.521	Irr.
393	do	1 4 13	1891	B, 10 inches	1,061	1,061	152		do	do			[b] 1.521	Irr.
394	do	1 4 13	1891	B, 10 inches	1,063	1,063	123		do	do			[b] 1.712	Irr.
395	do	1 4 13	1891	B, 10 inches	1,066	1,066	125		do	do			[b] 0.594	Irr.
396	do	1 3 18	1887	B, 10 inches	1,062	1,062	144		do	do			[b] 2.131	Irr.
397	do	1 3 18	1887	B, 10½ inches	1,064	1,064	140		do	do			[b] 1.011	Irr.
398	do	1 3 18	1888	B, 10 inches	1,075	1,075	138		do	do			[b] 0.605	Irr.
399	do	1 3 18	1888	B, 10 inches	1,075	1,075	106		do	do			[b] 0.188	Irr.
400	do	1 3 18	1888	B, 10 inches	1,074	1,074	130		do	do			[b] 0.563	Irr.
401	do	1 3 18	1888	B, 10 inches	1,071	1,071	146		do	do			[b] 2.212	Irr.
402	do	1 3 18	1888	B, 10 inches	1,065	1,065	116		do	do			[b] 3.176	Irr.
403	do	1 3 18	1888	B, 10 inches	1,064	1,064	134		do	do			[b] 1.424	Irr.
404	do	1 3 18	1888	B, 10 inches	1,061	1,061	116		do	do			[b] 0.594	Irr.
405	do	1 4 13	1887	B, 10 inches	1,057	1,057	147		do	do			[b] 2.254	Irr.
406	do	1 4 13	1887	B, 10 inches	1,058	1,058	122		do	do			[b] 1.026	Irr.
407	do	1 4 13	1892	B, 10 inches	1,059	1,059	115		do	do			[b] 0.484	Irr.

408	do	1	4	13	1892	B, 10½ inches	1,053	1,053	169		do	do			[c] 8.105	Irr.
409	do	1	3	18	1886	B, 7 inches	1,077		127		do	([d])			[c] 0.286	Irr.
410	do	1	3	18	1886	B, 7 inches	1,076		127		do	([d])			[c] 0.302	Irr.
411	do	1	3	18	1886	B, 7 inches	1,077		125		do	([d])			[c] 0.270	Irr.
412	do	1	3	18	1886	B, 7 inches	1,077		125		do	([d])			[c] 0.416	Irr.

[a] Included in cost of well.
[b] Flow of wells Nos. 391 to 412 is given for October, 1892.
[c] December, 1898.
[d] Wells 409 to 412 are pumped by 15-horsepower gas engine and centrifugal pump, raising 2 second-feet of water. These were artesian wells when sunk.

Wells in San Bernardino quadrangle.

No. of well.	Owner of well.	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	W.				Feet.	Feet.	Feet.						Sec.-ft.	
1	Riverside Water Co.	1	4	27	1887	11-inch pipe	1,014	1,014	115		Hard	Artesian			[a] 0.329	Dom.
2	do	1	4	27		11-inch pipe	1,015	1,015	118		do	do			[b] 0.284	Dom.
3	do	1	4	27		11-inch pipe	1,015	1,015	113		do	do			[b] 0.117	Dom.
4	do	1	4	27		11-inch pipe	1,016	1,016	111		do	do			[b] 0.153	Dom.
5	do	1	4	27		11-inch pipe	1,014	1,014	112		do	do			[b] 0.117	Dom.
6	do	1	4	27		11-inch pipe	1,016	1,016	120		do	do			[b] 0.150	Dom.
7	do	1	4	27	1888	7-inch pipe	1,013	1,013	128	BCS	do	do	$400		[b] 0.150	Dom.
8	do	1	4	27	1888	9-inch pipe	1,016	1,016	125	BCS	do	do	525		[b] 0.096	Dom.
9	do	1	4	27	1888	9.5-inch pipe	1,018	1,018	123	BCS	do	do	500			Dom.
10	do	1	4	27	1888	9-inch pipe	1,017	1,017	127	BCS	do	do	550			Dom.
11	do	1	4	27	1888	9-inch pipe	1,021	1,021	201	BCS	do	do	800		[b] 0.125	Dom.
12	do	1	4	27		9-inch pipe	1,020	1,020	141	BCSG	do	do	650			Dom.
13	do	1	4	27	1889	9-inch pipe	1,015	1,015	127	CSGB	do	do	525			Dom.
14	do	1	4	27	1889	9-inch pipe	1,014	1,014	125	CSGB	do	do	550		[b] 0.068	Dom.
15	do	1	4	22	1889	11-inch pipe	964	964	86	CSGB	do	do	480		[c] 0.442	Irr.
16	do	1	4	22	1889	9-inch pipe	981	981	123	CSBG	do	do			[c] 0.083	Irr.
17	do	1	4	22	1889	9-inch pipe	955	955	81	SCB	do	do			[c] 0.900	Irr.
18	do	1	4	22	1889	9-inch pipe	955	955	92	SGCB	do	do			[c] 0.361	Irr.
19	do	1	4	16	1889	9-inch pipe	972	972	225	SCGB	do	do			[b] 0.158	Irr.
20	do	1	4	16	1889	7-inch pipe	978	978	75	CSB	([d])	([d])			([d])	
21	do	1	4	16	1891	7-inch pipe	971	971	175	SCB	([d])	([d])			([d])	
22	do	1	4	16	1889	9-inch pipe	973	973	55	CSB	Hard	Artesian			0.173	Irr.
23	do	1	4	16	1889	9-inch pipe	974	974	121	SBCS	do	do			0.355	Irr.
24	do	1	4	22	1889	7-inch pipe	989	989	192	CSGB	do	do			[c] 0.175	Irr.
25	do	1	4	22	1889	9-inch pipe	968	968	81	SCGB	do	do			[c] 0.207	Irr.
26	do	1	4	22	1889	9-inch pipe	967	967	83	SCB	do	do			[c] 0.361	Irr.
27	do	1	4	22	1889	9-inch pipe	981	981	103	SCGB	do	do			[c] 0.952	Irr.

[a] 1890. [b] 1891. [c] 1896. [d] Well filled and covered with sand from flood and lost.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.		W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
28	Riverside Water Co.	1	4	22	1889	9-inch pipe	970	970	83	SCB	Hard	Artesian			[a]0.273	Irr.
29	do	1	4	22	1889	9-inch pipe	979	979	101	SCGB	do	do			[a]0.640	Irr.
30	do	1	4	22	1890	9-inch pipe	978	978	97	SCGB	do	do			[a]1.417	Irr.
31	do	1	4	22	1890	9-inch pipe	980	980	165	SCGB	do	do			[a]0.569	Irr.
32	do	1	4	22	1890	9-inch pipe	979	979	165	SCBG	do	do			[a]0.616	Irr.
33	do	1	4	27	1891	9.5-inch pipe	1,012	1,012	330	SGCR	do	do			[b]3.28	Dom.
34	do	1	4	27	1891	9.5-inch pipe	1,012	1,012	326	CSGR	do	do				Dom.
35	do	1	4	22		9.5-inch pipe	977	977	82	CSGB	do	do	$255		[c]0.860	Irr.
37	do	1	4	27		9.5-inch pipe	1,012	1,012	249	CSGR	do	do				Dom.
38	do	1	4	1	1892	7-inch pipe	1,083	1,083	187	SGC	do	do	662		[d]0.027	Irr.
39	do	1	4	1	1893	9.5-inch pipe	1,083	1,083	396	SBCRG	do	do			[d]0.714	Irr.
42	do	1	4	27	1893	9.5-inch pipe	1,011	1,011	344	CSB	do	do				Dom.
43	do	1	4	1	1894	9.5-inch pipe	1,086	1,086	420	SGC	do	do	630		[e]1.452	Irr.
44	do	1	4	22	1896	9-inch pipe	979	979	133		do	do	250		[a]0.971	Irr.
45	do	1	4	22	1896	9-inch pipe	979	979	173	SB	do	do	420			Irr.
47	do	1	4	3	1898	9-inch pipe	1,025	1,025	168	SB	do	do	500			Irr.
51	do	1	4	22		8-inch pipe	954	954	78		do	do				Irr.
52	do	1	4	22		8-inch pipe	955	955	94	SCG	do	do				Irr.
53	do	1	4	22	1898	8-inch pipe	956	956	68	SCG	do	do				Irr.
54	do	1	4	22	1898	8-inch pipe	957	957	68		do	do				Irr.
55	do	1	4	22	1898	7-inch pipe	958	958	92		do	do				Irr.
56	do	1	4	22	1898	7-inch pipe	959	959	75		do	do				Irr.
57	do	1	4	22	1898	8-inch pipe	960	960	92	CS	do	do	128			Irr.
58	do	1	4	22	1898	7-inch pipe	960	960	87	CBGS	do	do	157		[f]0.456	Irr.
59	do	1	4	22	1898	8-inch pipe	961	961	85	SCB	do	do	138		[f]0.622	Irr.
60	do	1	4	22	1898	7-inch pipe	961	961	93	SCB	do	do	173		[f]0.456	Irr.
61	do	1	4	22		8-inch pipe	952	952			do	do				Irr.
62	do	1	4	15	1898	8-inch pipe	985	985	183	SCG	do	do			[f]0.34	Irr.
65	do	1	4	2	1900	10-inch pipe	1,040	1,040	540	GCS	Soft	do			2.89	Irr.
66	do	1	4	2	1900	10-inch pipe	1,035	1,035	580	GCSR	Hard	do			2.606	Irr.
67	Wm. Roach	2	4	6	1889	7-inch pipe	904	852	130		Soft	10 wind	200	$160	0.015	Irr; dom.
68	do	2	4	6	1875	7-inch pipe	905	852	70		do	12 wind	105	130	0.006	Irr.
69	Mrs. Douglas	2	4	6	1893	7-inch pipe	895	835	112		do	Wind			0.015	Irr; dom.
70	Louise Peña	2	5	12	1888	D, 3 by 4 feet	835	815	22		Hard	do		110	Small.	Dom.
71	P. Evans	2	5	12	1900	10-inch pipe	840	840	400			Artesian			1.000	Irr.
72	P. Baca	2	5	12	1899	D, 3 by 3 feet	852	832	22		Hard	Hand	20		Small.	Dom.
73	W. L. Zader	1	4	29	1894	D, 3 feet dia	980	930	52		do	8 wind	40	35	do	Dom.
74	D. Jones	1	4	29	1888	D, 3 feet dia	980		70			Wind	100	200		
75	T. J. Smith	1	4	30	1890	D, 3 feet dia	974		38			do				
76	Mrs. B. R. Atkins	1	4	30	1897	D, 3 feet dia	980	938	59		Hard	9 wind		500	Small.	Dom.

77		1	4	30		D, 3 by 3 feet	886	871	17			Hand				Dom.
78		1	4	30		D, 3 by 3 feet	875	871	6			do				Dom.
79	Thos. McGraw	1	5	35	1895	D, 4 by 4 feet	875	837	39	SCG	Soft	do	70	14	Small.	Dom.
80	Henry Carson	2	5	10	1900	D, 3 feet dia	831	784	49	SGR	do		40			Dom.
81	Dan. Baker	2	5	10	1885	6-inch pipe	826	786	60		do	Hand		20		Dom.
82	Mrs. Burgess	1	5	34		D, 4 by 4 feet	988	838	150			Wind				Not used.
83	T. Pulley	2	5	10	(g)	B, 20 inches	881	808	89							
84	Mrs. L. M. Henry	2	5	10	1898	6-inch pipe	895	787	128		Hard	Wind				Irr; dom.
85	T. Pulley	2	5	10	1896	D, 3 feet dia	850	780	72		do	do	50	120		Irr; dom.
86	John Miller	2	5	10	1900	D, 3 feet dia	866	800	69		Soft	do	40			Dom.
87	Ed. Bridson	2	5	15	1898	7-inch pipe	840	780	100	GS	Hard	10 wind	150	150		Dom; st.
88	J. Rogerson	2	5	15		D, 4 by 4 feet	830	794	37			Hand				Dom.
89	Mrs. A. Parks	2	5	15		7-inch pipe	810	793	28		Hard	Wind				Dom; st.
90	H. C. Parks	2	5	9	1887	D, 3 feet dia	850	784	75		do	do	325	180		Dom; st.
91	Scott La Rue	2	5	9	1900	D, 3 feet dia	845	742	107	SG		do	100	285		Dom; st.
92	Emuel Spooner	2	5	8	1896	D, 4 by 4 feet	850	750	105	SG	Hard	do	115			Dom; st.
93	do	2	5	8	1900	D, 4 by 4 feet	850	750	107	SG			125			
94	W. J. Thomas	2	5	7	1900	D, 4½ by 4 feet	847	817	35	SGB	Soft		70			Dom.
95	E. Thomas	2	5	7	1899	D, 3 by 3 feet	850	814	41	SG	do	Wind	75	150		Irr.
96	do	2	5	7	1894	D, 3 by 3 feet	841	817	26		do	Hand	40			Dom.
97	Mrs. H. M. Thurber	2	6	12	1896	D, 5 feet dia	800	782	28		do	Wind				Irr; dom.
98	F. D. Lewis	2	6	13		D, 4 by 4 feet	795	775	40		do	10 wind				Dom.
99		2	6	12		D, 4 by 4 feet	789	770	31			do				Dom.
100	John Parkhurst	2	6	12	1898	D, 6 feet dia	818	807	13.5	SR	Soft	12 wind	100	135		Dom.
101	J. R. Johnston	2	5	6		Pipe line										Dom.; st.
102	I. McBride	2	6	12	1892	D, 3.5 by 3.5 feet	813	787	55	SR	Soft	8 wind	80	100	Small.	Dom.
103	Milo Gilbert	1	4	24	1900	7-inch pipe	1,004	864	220			12 wind				
104	Riverside Trust Co	1	4	24	1898	10-inch pipe	1,077	1,077	506	CSGR	Hard	Artesian			1.600	Irr.
105	do	1	4	24	1898	10-inch pipe	1,071	1,071	531	CSG	do	do			1.200	Irr.
106	do	1	4	24	1898	10-inch pipe	1,065	1,065	517	CSGR	do	do			1.400	Irr.
107	do	1	4	23	1899	10-inch pipe	1,045	1,045	675	CSGR	do	do			1.500	Irr.
108	do	1	4	24	1899	10-inch pipe	1,076	1,076	568	CSGR	do	do			2.040	Irr.
109	do	1	4	26	1899	10-inch pipe	1,019	1,019	554	CSGR	do	do			0.400	Irr.
110	do	1	4	13	1899	10-inch pipe	1,052	1,052	580		do	do				Irr.
111	do	1	4	13	1899	10-inch pipe	1,061	1,061	537	CSGR	do	do			2.600	Irr.
112	do	1	4	13	1899	10-inch pipe	1,066	1,066	577	CSGR	do	do			1.200	Irr.
113	do	1	4	13	1899	10-inch pipe	1,069	1,069	505	CSGR	do	do			1.040	Irr.
114	do	1	4	13	1900	10-inch pipe	1,079	1,079	478	CSGR	do	do			3.000	Irr.
115	Gage Canal Co	1	4	26	1891	10-inch pipe	1,033	1,033	656		do	do			0.089	Irr.
116	do	1	4	26	1891	10-inch pipe	1,034	1,034	534		do	do			0.956	Irr.
117	do	1	4	26	1891	10-inch pipe	1,034	1,034	582		do	do			0.770	Irr.
118	do	1	4	26	1891	10-inch pipe	1,034	1,034	482		do	do			1.026	Irr.
119	do	1	4	26	1891	10¼-inch pipe	1,034	1,034	320		do	do			0.064	Irr.
120	do	1	4	26	1891	10-inch pipe	1,034	1,034	784		do	do			1.089	Irr.
121	do	1	4	23	1888	10¼-inch pipe	1,036	1,036	196		do	do			0.550	Irr.
122	do	1	4	23	1888	10¼-inch pipe	1,036	1,036	190		do	do			0.979	Irr.
123	do	1	4	23	1889	10-inch pipe	1,036	1,036	142		do	do			0.188	Irr.
124	do	1	4	23	1889	10¼-inch pipe	1,036	1,036	148		do	do			0.121	Irr.

[a] 1896. [b] 1891. [c] 1892. [d] 1900. [e] 1894. [f] 1898. [g] Not finished.

NOTE.—No. 48 is No. 335 of Redlands quadrangle; no record for Nos. 36, 40, 41, and 49; Nos. 50, 63, and 64 are Nos. 334, 336, and 337, respectively, of Redlands quadrangle; No. 46 is also in Redlands quadrangle.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T.R.S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	R.				*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
125	Gage Canal Co	1	4	24	1886	7-inch pipe	1,037	1,037	141		Hard	Artesian			2.330	Irr.
126	do	1	4	13	1886	7-inch pipe	1,037	1,037	181		do	do			1.928	Irr.
127	do	1	4	13	1891	10-inch pipe	1,037	1,037	426		do	do			5.901	Irr.
128	do	1	4	13	1891	10-inch pipe	1,037	1,037	472		do	do			1.874	Irr.
129	do	1	4	13	1891	10-inch pipe	1,048	1,048	518		do	do			1.874	Irr.
130	do	1	4	13	1891	10-inch pipe	1,049	1,049	338		do	do			1.264	Irr.
131	do	1	4	13	1891	10-inch pipe	1,049	1,049	380		do	do			0.770	Irr.
132	do	1	4	13	1891	10-inch pipe	1,049	1,049	386		do	do			1.424	Irr.
133	do	1	4	13	1891	10-inch pipe	1,052	1,052	198		do	do			5.314	Irr.
134	do	1	4	13	1891	10-inch pipe	1,057	1,057	124		do	do			1.299	Irr.
135	do	1	4	13	1891	10-inch pipe	1,055	1,055	116		do	do			2.746	Irr.
136	do	1	4	13	1891	10-inch pipe	1,057	1,057	134		do	do			5.663	Irr.
155	do	1	4	13	1892	10-inch pipe	1,051	1,051	193		do	do			8.239	Irr.
156	do	1	4	13	1892	10-inch pipe	1,046	1,046	192		do	do			8.315	Irr.
157	do	1	4	13	1892	10½-inch pipe	1,044	1,044	390		do	do			4.835	Irr.
158	do	1	4	13	1892	10-inch pipe	1,042	1,042	224		do	do			5.697	Irr.
159	do	1	4	13	1885	7-inch pipe	1,045		123		(a)	(a)			1.923	Irr.
160	do	1	4	13	1885	7-inch pipe	1,045		133		(a)	(a)			0.473	Irr.
161	do	1	4	13	1885	7-inch pipe	1,045		133		(a)	(a)			3.015	Irr.
162	do	1	4	13	1885	5-inch pipe	1,048		139		(a)	(a)			8.217	Irr.
163	do	1	4	13	1885	7-inch pipe	1,048		211		(a)	(a)			4.641	Irr.
164	do	1	4	13	1885	7-inch pipe	1,046		100		(a)	(a)			0.579	Irr.
169	do	1	4	13	1890	10-inch pipe	1,037	1,037	300			Artesian			5.901	Irr.
170	Riverside Trust Co	1	4	23	1900	10-inch pipe	1,011	1,011	582			do			6.131	Irr.
171	Bloomington Land Co.	1	5	22	1900	12-inch pipe	1,100	858	454	SGCR		do	$1,200			Not used.
172	D. Johnson	1	4	8		8-inch pipe	1,095	1,081	283		Soft		600			Not used.
173	Fox, Archibald & Lantz.	1	4	8			1,089					Centrifugal; 10 gas			0.414	Irr.
174	Jas. Lamb	1	4	8	1894	8-inch pipe	1,097	1,083	102		Soft	do	200	$1,800	0.400	Irr.
175	Jas. Barnhill	1	4	8		8-inch pipe	1,097					Centrifugal; 15 electric.			0.800	Irr.
176	City of Colton	1	4	8	1899	10-inch pipe	1,087	1,070	490		Soft	Centrifugal; electric			0.834	Irr; dom.
177	do	1	4	8	1899	8-inch pipe	1,084	1,068	90		do	do			0.200	Irr; dom.
178	G. W. Curtis	1	4	24	1895	7-inch pipe	1,088	1,063	85	SCG	Hard	8-wind	130	70	0.002	Irr; dom.
179	J. J. Curtis	1	4	24	1892	7-inch pipe	1,088	1,063	90		do	do	150	120	0.003	Irr; dom.
180	A. C. Harvey	1	4	24	1898	7-inch pipe	1,088	1,088	600	GC	do	Centrifugal; 12 gas	400	1,200	2.250	Irr.
181	W. A. Thomas	1	4	24			1,078	1,076				Artesian				
182	L. S. Dart	1	4	25	1890	7-inch pipe	1,075	1,055	80		Hard	12 wind	150		0.002	Dom.

183	Anderson estate	1	4	25		8-inch pipe 4.5-inch pipe	1,093		450 150		Soft	Centrifugal; 25 gas		2,275	0.250	Irr.
184	A. Hunt	1	4	27	1889	7-inch pipe	1,005	1,005	127		Hard	Artesian	200		0.100	Irr; dom.
185	do	1	4	27	1889	7-inch pipe	1,001	1,001	57			do	90		0.800	Irr.
186	do	1	4	27	1895	9½-inch pipe	1,004	1,004	280	SCG		do	1,100		0.400	Irr.
187	do	1	4	27	1894	7-inch pipe	1,007	1,007	200			do	500			Irr.
188	No record															
189	E. M. Cooley	1	4	27	1889	7-inch pipe	1,019	959	86		Hard	12 wind	150	100		Irr; dom.
190	H. L. Drew	1	4	21		3-inch pipe	980	980	200		do	Artesian			0.010	Dom.
191	C. C. Cooley	1	4	27	1885	7-inch pipe	993	928	85		do	12 wind	150	100		Dom.
192	P. Filance	1	4	27	1887	10-inch pipe	983	983	250		Soft	Artesian	1,000		1.200	Irr.
193	Filance estate	1	4	27	1880	3-inch pipe (3)	984	984	75 85 90		do	do			0.900	Irr; dom.
194	O. A. Byrne	1	4	21		2-inch pipe	984	980				Hand		5		Dom.
195	Harry Whaley	1	4	34	1890	7-inch pipe	1,150	1,115	100		Hard	8 wind			0.001	Dom.
196	Thomas N. Hunt	1	4	34	1890	D, 3 feet dia	1,117	1,000	123			16 wind	750	100		Dom.
197	Mr. Blair	1	4	34	1899	D, 5 by 5 feet	1,115	1,109	16			Never used				
198	Ignacio Reyes	1	4	34	1895	Dug	1,182	1,172	13		Soft		15	3		Dom.
199	Washington School	1	4	27		7-inch pipe	1,043	966	129			8 wind		90		Dom.
200	S. A. Pooles	1	4	33	1890	7-inch pipe	1,015	955	75		Hard	12 wind		500	0.005	
201	Fred Pooles	1	4	33	1884	7-inch pipe	955	907	52			8 wind				Dom.
202	Mrs. C. A. Peake	1	4	33	1880	2-inch pipe	950	936	18		Hard	Hand	10			Dom.
203	Chas. Green	1	4	33		3-inch pipe	944		3		do	Wind				Dom.
204	J. D. Warner	1	4	28	1884	1½-inch pipe	938	927	13		do	Hand	10			Dom.
205	do	1	4	28	1898	1¾-inch pipe	926	916	13		do	do	8			Dom.
206	do	1	4	28	1894	10-inch pipe	941	935	515	GCR	do		2,455			
207	Geo. Cooley, sr	1	4	27	1894	7-inch pipe	978	952	72	G		12 wind		125	0.005	Irr; dom.
208	C. A. Poole	1	4	27	1900	7-inch pipe	1,002	984	50	SG	Hard	Hand	110			Dom.
209	A. A. Warren	1	4	33	1885	2-inch pipe	936	929	25		do	12 wind	15	150	0.002	Irr; dom.
210	W. Riverside Water Co.	1	4	32			950	944	112	GR	do	30 compressor		1,275		Irr.
211	J. M. Snodgrass	1	4	28	1898	D, 10 feet dia	931	927	13	GS	do	Bucket pump; eng	50	600	0.500	Irr.
212	do	1	4	28	1898	D, 2 feet dia	923	920	7.5	GS	do	12 wind	10	50	0.003	Irr.
213	A. A. Warren	1	4	33	1897	2-inch pipe	943	936	15		do	Hand	15	5		Dom.
214	S. P. R. R. Co	1	4	21	1882	7-inch pipe	958	915	45		do	12 wind			0.005	Dom.
215	Frank Parody	1	4	28	1900	Dug	955	934	33	S	do	Hand		12		Dom.
216	Martin Gahm	1	4	21	1888	D, 3 by 3 feet	964	927	41		do	8 wind	50	75	0.005	Dom.
217	W. H. Wells	1	4	21	1893	D, 2.5 by 2.5 feet	966	928	44	SG	do	Hand	6			Dom.
218	C. G. Turner	1	4	21	1895	7-inch pipe	966		70		do	12 wind				
219	G. B. Kinyon	1	4	21	1888	D, 3 by 3 feet	948	934	25		Soft	Wind	25	500		Irr; dom.
220	J. F. Stuchberry	1	4	21	1886	D, 3.5 by 3.5 feet	952	933	22	CSG	do	8 wind	30	90	0.007	Irr; dom.
221	J. H. Vaughan	1	4	21	1886	D, 4 feet dia	955	934	27		Hard	12 wind	48	75	0.009	Irr; dom.
222	Alfred Vaughan	1	4	21	1900	D, 4 feet dia	959	928	34			do	62	155		Irr.
223	W. L. Vaughan	1	4	21	1884	D, 4 feet dia	965				Hard	do			0.009	Irr; dom.
224	H. D. Young	1	4	21	1890	D, 2 feet dia	963	931	40		Soft	Hand	40			Dom.

[a] Wells 159 to 164 are connected. From this group a 40-horsepower gasoline engine and centrifugal pump raise 2.66 second-feet of water. These wells were artesian until 1900.

NOTE.—Flow of wells Nos. 104 to 114 and 170 was measured on completion of wells. Flow of wells Nos. 115 to 136 and 155 to 164 is given for October, 1892. No other records of flow of these wells. Wells Nos. 137 to 154 and 165 to 168 are in Redlands quadrangle, as are Nos. 391 to 412. Flow of these wells is given for October, 1892.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			Feet.	Feet.	Feet.						Sec.-ft.	
225	J. H. Dodson	1 4 21	1885	D, 4 feet dia	969	926	50		Soft	8 wind		$105	0.003	Irr; dom.
226	Henry Kaiser	1 4 21	1892	D, 4 feet dia	964	922	43		do	12 wind	$84		0.006	Irr; dom.
227	H. C. Dodson	1 4 21	1892	D, 2 feet dia	968	928	55		do	8 wind		212		Irr; dom.
228	John Benner	1 4 21	1880	D, 4 feet dia	970	916	62			12 wind			0.002	Irr; dom.
229	Tom Moran	1 4 21		D, 4 feet dia	974	921	54		Hard	Hand			Small.	Dom.
230	T. Allen	1 4 21	1880	D, 4 feet dia	978	924	68		Soft	14 wind		155	0.001	Dom.
231	S. A. Woodard	1 4 21	1882	D, 4.5 feet dia	984	928	69		Hard	12 wind			0.009	Irr; dom.
232	Los Angeles Bdg. Co.	1 4 21		D, 4 by 4 feet	1,000	Dry.	70			10 wind				
233	J. A. Coburn	1 4 16	1890	D, 4 by 4 feet	1,000	934	80		Hard	12 wind			0.005	Irr; dom.
234	Miss B. Top	1 4 16			1,038	1,038	3			8 wind	5	65	0.002	Irr; dom.
235	Byron Waters	1 4 16	1893	D, 9.5 by 9.5 feet and 5 by 5 feet.	1,019	991	28			Centrifugal; 3 electric.	300	376	0.6	Irr; dom.
235a	do	1 4 16	1889	3-inch pipe	1,019		220			Artesian	700		0.005	Irr; dom.
236	Dr. Rowl			Pipe						do				
237	do			Pipe					Sulph.	do				
238	Homer Jones	1 4 16	1895	3-inch pipe	1,023	1,010	300		do	8 wind			0.002	Irr; dom.
239	Mrs. M. G. Hammel	1 4 16			1,008	1,000	83		Hard	do		75	0.002	Irr; dom.
240	Riverside Trust Co	1 4 23		7-inch pipe	1,000				do	Hand				Dom.
241	F. S. West	1 4 23	1897	2-inch pipe	998									Irr; dom.
242	Mrs. E. A. Paine	1 4 22	1896	3-inch pipe	1,000	1,000	109	SCG	Hard	Artesian		75	0.04	Irr; dom.
243	M. B. Warren	1 4 22	1885	4-inch pipe	996	996	125		do	do			0.01	Irr; dom.
243a	do	50′ SE. from 243	1899	3-inch pipe	997	997	130	SCG		do			0.25	Irr.
244	do	1 4 22	1880	2-inch pipe	998	998	125		Hard	do			0.041	Irr; dom.
244a	do	20′ SW. from 244	1899	3-inch pipe	997	997			do	do			0.178	Irr; dom.
245	C. E. Bishop	1 4 23	1882	3-inch pipe	1,001	1,001	94		do	do	125		0.02	Irr; dom.
245a	do	1 4 23	1888	7-inch pipe	1,004	1,004	94	SC	do	do			0.02	Irr; dom.
246	Wm. E. Everett	1 4 22	1898	3-inch pipe	1,001	1,001	96		do	do	100		0.25	Irr; dom.
247	Bob Gomer	1 4 15	1890	3-inch pipe	984				do					
248	John Welsh	1 4 23		3-inch pipe	1,007	1,007	100		Hard	Artesian			0.083	Irr; dom.
249	S. B. Parish	1 4 14	1892	10-inch pipe	1,019	1,019	540		Soft	do	2,500		0.40	Irr.
250	do	1 4 14	1885	6-inch pipe	1,017	1,015	104		Hard		300			
251	do	1 4 14	1889	2-inch pipe	1,016		100		do		150			
252	do	1 4 14	1870	1½-inch pipe	1,014	1,014	83		do	Artesian			0.004	
253	Mrs. Elizabeth Case	1 4 14	1898	3-inch pipe	1,007	1,007	91		do	do	85		0.115	Irr; dom.
254	do	1 4 14	1892	7-inch pipe	1,009	1,009	260		do	do	500		0.2	Irr.
254a	W. G. Merrilees	1 4 14	1893	7-inch pipe	1,009	1,009	211		do	do			0.14	Irr.
254b	do	1 4 14	1897	3-inch pipe	1,009	1,009	86		do	do			Small.	Irr.
255	Wm. Stewart	1 4 15	1898	8-inch pipe	1,004	1,004	315		do	do			[a] 1.14	Irr.
256	do	1 4 15	1898	9-inch pipe	1,005	1,005	85		do	do			[b] 0.2	Irr.

257	do	1	4	15		1½-inch pipe	1,004	1,004				do	do			Small.	Dom.
259	do	1	4	15		7-inch pipe	1,002					do					Irr.
260	John Sullivan	1	4	14	1874	2-inch pipe	1,021		82					100		(c)	Irr; dom.
261	do	1	4	14	1893	3-inch pipe	1,024	1,024	210		Hard	Artesian		325		0.062	
263	do	1	4	14	1884	7-inch pipe	1,025	1,023	84					80		(d)	
264	do	1	4	14	1871	2-inch pipe	1,037		90							(d)	
265		1	4	14	1892	2-inch pipe	1,022		92			Artesian				0.002	Dom.
266	Wm. Baker	1	4	14	1870	1.5-inch pipe	1,022	1,022	96		Hard	do		130		Small.	Dom.
267	do	1	4	14	1899	3-inch pipe	1,024	1,024	271	SGC	do	do		435		0.178	Dom; irr.
268	P. J. Clevenger	1	4	14		2-inch pipe	1,030					10 electric; centrifugal.				(e)	
269	do	1	4	14	1897	10-inch pipe	1,043		150							0.5	Irr.
270	Henry Warren	1	4	14	1883	2-inch pipe	1,033	1,023	106					150		(d)	Dom; irr.
271	do	1	4	14	1890	3-inch pipe	1,033	1,023	100			12 wind		100	160	(d)	Dom; irr.
272	John Sullivan	1	4	14	1898	3-inch pipe	1,024	1,024	214		Hard	Artesian		300		0.178	Irr.
273	Henry Warren	1	4	14	1880	7-inch pipe	1,036	1,026	106					200		(e)	Not used.
274	do	1	4	14	1880	7-inch pipe	1,038	1,028	220					500		(f)	Not used.
275	do	1	4	14	1893	10-inch pipe	1,039	1,039	640			Artesian		3,000		0.386	Irr.
276	Frank Feri	1	4	14		2-inch pipe	1,034					Hand				(g)	Dom.
277	G. Renwick	1	4	8		6-inch pipe	1,090	1,055	186		Soft	8 wind				Small.	Dom.
278	Orange Land and Water Co.	1	4	8		7-inch pipe	1,089	1,069	225			do	Centrifugal; 20 compressor; 3 wells in group together.			1.64	Dom; irr.
279	Callahan estate	1	4	20	1886	D. 4 by 4 feet	1,009	933	84			12 wind					
280	E. Memory	1	4	20	1886	D. 4 by 4 feet	982	927	60		Hard	do				Small.	Dom.
281	F. A. Cleveland	1	4	8	1898	2-inch pipe	1,072		90			8 wind		47	40	Small.	Dom.
282	C. H. Westmyer	1	4	8	1897	3-inch pipe	1,069	1,062	94	GSC	Soft	do		74	100	Small.	Dom; irr.
283	W. W. Brison	1	4	9	1899	2-inch pipe	1,062	1,052	99	SG	do	10 wind		100	200	Small.	Dom.
284	G. F. Woods	1	4	9	1900	8-inch pipe	1,059	1,049	140		do	do		300	350	0.008	Dom; irr.
285	do	1	4	9	1887	7-inch pipe	1,060	1,060	300							None.	
286	City of Colton	1	4	8		10-inch pipe (2) 7-inch pipe (2)	1,065		200–640			Centrifugal: 20 electric.			2,000	2.500	Dom; irr.
287	Isaac Jameson	1	4	8	1898	8-inch pipe	1,070	1,050	90		Hard	12 wind		126	275	0.015	Dom; irr.
288	J. Collins	1	4	8	1887	3-inch pipe	1,054		75			10 wind				Small.	Irr; dom.
289	J. C. Ralphs	1	4	9	1899	10-inch pipe	1,047	1,016	202		Soft	12 wind		500	200	Small.	Irr; dom.
290	Los Angeles Bdg. Co.	1	4	9	1893	10-inch pipe	1,052		160		do	8 gas; centrifugal				0.8	Irr.
291	V. Herkelrath	1	4	15	1882	2-inch pipe	979	979			do	Artesian		70		0.072	Dom.
292	do	1	4	15	1880	2-inch pipe	980	980			do	do		175		0.119	Irr.
293	Mrs. Nowland	1	4	15	1875	2-inch pipe	980	980	160			do		275			Irr.
294	M. H. Hurd	1	4	15	1887	2-inch pipe	983				Hard	do					Dom.
295	Mrs. N. H. Ball	1	4	15	1894	7-inch pipe	996	996	253		Soft	do		500		0.262	Irr.
296	Los Angeles Bdg. Co.	1	4	9		10-inch pipe	1,051	1,049	446			do				0.4	Irr.
297	do	1	4	9		10-inch pipe	1,050	1,048	451			do				0.4	Irr.
298	Mrs. N. H. Ball	1	4	15	1886	3-inch pipe	992	992	107		Soft	do		250			Dom.
299	W. Beck	1	4	15	1892	3-inch pipe	998	998	204		do	do					Irr.
300	H. Klueter	1	4	10	1885	3-inch pipe	1,006	1,006	200		do	do		300		0.074	Dom; irr.
301	do	1	4	10	1887	3-inch pipe	1,005	1,005	206		Soft	do		328			Irr.
302	do	1	4	10	1887	3-inch pipe	1,005	1,005	132		do	do		159		0.518	Irr.
303	do	1	4	10	1897	3-inch pipe	1,003	1,003	135		do	do		125		0.006	Irr.

[a] 1899.
[b] 1898.
[c] Stopped flowing in 1895.
[d] Stopped flowing in 1898.
[e] Stopped flowing in 1889.
[f] Stopped flowing in 1890.
[g] Stopped flowing in May, 1900.

NOTE.—No record for Nos. 258 and 262.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T.R.S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
304	Stephen Wood	1 4 11	1894	3-inch pipe	1,010	1,010	160		Soft	Artesian			Small.	Dom.
305	W. B. Barton	1 4 14	1883	2-inch pipe	1,041		100		do	12 wind		$216	Small.	Dom.
306	Stephen Wood	1 4 11	1880	3-inch pipe	1,022		164			8 wind			Small.	Stock.
307	F. M. Keller	1 4 11	1882	3-inch pipe	1,024	1,024	267		Soft	Artesian	$500		0.02	Dom.
308	W. B. Barton	1 4 13	1892	10-inch pipe	1,045	1,033	115		do	9 gas; centrifugal			0.209	Irr.
309	A. J. Downer	1 4 13	1889	3-inch pipe	1,045		190		do	12 wind	125	50	Small.	Dom.
310	Edwin Martin	1 4 13		3-inch pipe	1,045	1,033	215		do	Hand			Small.	Dom.
311	Lucas Hoagland	1 4 13	1876	2-inch pipe	1,049	1,039	80		do	do	75		Small.	Dom.
312	do	1 4 13	1884	3-inch pipe	1,050	1,040	250		do	8 wind	250	75	Small.	Stock.
313	do	1 4 12	1884	2-inch pipe	1,047		100		do		100			Not used.
314	R. F. Garner	1 4 10	1888		1,019		200			Artesian			Small.	Dom.
315		1 4 12		10-inch pipe	1,059	1,059	682+			do			0.123	Stock.
		N. W.												
316	Geo. M. Cooley	1 4 36	1892	7-inch pipe	1,150	1,108	66		Soft	12 wind		500		Irr; dom.
317	do	1 4 36	1895	11-inch pipe	1,150	1,108	80			9 gas		1,500	0.6	Irr.
317a	do	1 4 36	1895	10-inch pipe	1,150	1,108	80			9½ cylinder pumps				Irr.
318	E. J. Stiles	1 4 35	1898	7-inch pipe	1,196	1,157	48		Soft	10 wind	40	160	Small.	Dom; st.
319	Jas. Dickson	1 4 35	1888	10-inch pipe	1,179	1,145	44		do	12 wind		135	Small.	Dom.
320	J. G. Wood	1 4 35	1884	7-inch pipe	1,124	1,090	44		do	do		200	Small.	Dom.
321	do	1 4 36	1885	11-inch pipe	1,140	1,092	64		do	Cylinder pump; 5 gas	240	600	0.125	Irr.
322	M. E. Myers	1 4 35	1890	2-inch pipe	1,111	1,089	310		Hard	12 wind				Dom; irr
		S. W.												
323	J. S. Bean	1 4 3	1889	3-inch pipe	1,108	1,108	210			Artesian	200		0.1	Irr.
324	do	1 4 3	1898	10-inch pipe	1,108	1,108	524		Hard	do	1,100		0.9	Irr.
		N. W.												
325	J. F. Johnson	1 4 34	1890	7-inch pipe	1,098	1,076	39		do	Hand				Not used.
326	Oscar Perris	1 4 26			1,177		96			Steam; power				Irr.
327	S. G. Ramsey	1 4 25	1896	10-inch pipe	1,190	1,125	90	SC		Power; 10 gas	160	1,200	0.3	Irr.
328	Saml. S. Ford	1 4 26	1898	D, 3 feet dia	1,185	No water.	58			Wind		225	None.	
329	Mescupiabe L. & W. Co.	1 4 23	1899	7-inch pipe	1,288	1,143	402		Hard	Power; 15 gas	1,200	2,000	0.5	Dom; st; irr.
330	do	1 4 26	1892	7-inch pipe	1,222	No water.	102			Wind	300	250	None.	
331	Mrs. Anne C. Severance.	1 4 26	1895	7-inch pipe	1,227	No water.	106			12 wind	300	900	None.	
332	Mrs. S. A. Smith	1 4 27	1894	7-inch pipe	1,224	1,124	140		Soft	16 wind		800	0.010	Irr; dom.
333	F. M. Johnson	1 4 34	1899	10-inch pipe	1,117	1,095	600			10 gas; cylinder pump.	1,160	800	0.230	Irr.
334	do	1 4 34	1880	12-inch pipe	1,112	1,084	40			Wind			Small.	St; dom.

335	H. H. Fitting	1	4	35	1885	7-inch pipe	1,124		44		Soft	do			Small.	St; dom
336	do	1	4	35	1888	D, 6 by 6 feet	1,135	No water.	47			4½ gas; cylinder pump.	100	500	None.	
337	do	1	4	35	1886	3-inch pipe	1,131		325				1,000		Dry.	
338	C. Hansen	1	4	35	1895	7-inch pipe	1,127	1,090	39		Soft	8 wind		200	Small.	St; dom.
339	N. Hoien	1	4	35	1895	7-inch pipe	1,127	1,090	47		do				Small.	St; dom.
340	John Anderson	1	4	34	1885	7-inch pipe	1,130		90		do	8 wind	114	100	Small.	St; dom.
341	H. N. Stones	1	4	34	1884	7-inch pipe	1,141	1,087	85		do	do		125	Small.	St; dom.
342	M. F. Swing	1	4	34	1891	7-inch pipe	1,151		93		do	12 wind		220		St; dom.
343	do	1	4	34	1894	7-inch pipe	1,152		87		do	do			Small.	Irr.
344	A. R. Togg	1	4	34	1891	7-inch pipe	1,160		100		do	do				Irr; dom.
345	F. L. Smith	1	4	34	1897	7-inch pipe	1,163		106		do	10 wind	105	135	0.002	Irr; dom.
346	John W. Anderson	1	4	34	1880	7-inch pipe	1,165	1,103	70		do	do	75	175	0.002	Irr.
347	do	1	4	34	1900	7-inch pipe	1,166	1,103	113		do	16 wind	125	225	0.004	Irr.
348	S. E. Pearson	1	4	27	1899	7-inch pipe	1,182	1,107	104		do	12 wind	135	60	Small.	Irr; dom.
349	R. Meacham	1	4	27	1900	7-inch pipe	1,183		110		do	do			Small.	Irr; dom.
350	do	1	4	27	1890	7-inch pipe	1,172	No water.	64			do			None	
351	J. H. Taylor	1	4	27	1896	7-inch pipe	1,188	No water.	62		Soft	8 wind	50	100	None.	
352	W. G. Warner	1	4	27	1899	7-inch pipe	1,189	1,119	80			10 steam				Not used.
353	F. D. Olmstead	1	4	27	1895	7-inch pipe	1,190		101		Soft	12 wind		100	Small.	Irr; dom.
354	S. F. Kelley	1	4	28	1897	7-inch pipe	1,170	1,121	115		Hard	8 wind			Small.	Irr; dom.
355	S. F. Kelley et al	1	4	28	1900	12-inch pipe	1,185	1,127	208			20 electric; centrifugal.	1,700	1,171	0.9	Irr.
355a	do	1	4	28	1899	10-inch pipe	1,185	1,127	460							
356	H. C. Ward	1	4	28		7-inch pipe	1,177	1,118	120			12 wind			Small.	Irr.
357	S. H. Johnson	1	4	28	1885	7-inch pipe	1,182	1,122	84		Soft	10 wind		250	Small.	Dom.
358	H. Giddings	1	4	28	1898	7-inch pipe	1,205	1,148	73		do	15 wind		125		Dom.
359	W. G. Rowland	1	4	28	1893	7-inch pipe	1,224	1,156	112		Hard	Geared pump; 3 gas	125	625	0.1	Irr.
360	Fred. Heilemann	1	4	32	1889	7-inch pipe	1,227	1,147	146		do	16 wind	200	750	0.008	Irr; dom.
361	do	1	4	32	1894	7-inch pipe	1,228	1,148	129		do	18 wind			0.012	Irr; dom.
362	do	1	4	29	1890	10-inch pipe; 8-inch pipe; 6⅝-inch pipe	1,245	1,155	1,025				7,000		(a)	
363	B. E. Wheeler	1	4	29	1898	10-inch pipe	1,258	1,152	125		Hard	Plunger pump; 5 gas	300	800		Irr; dom.
364	F. Alvarado	1 S. W.	4	32	1900	7-inch pipe	1,188	1,135	93							Not used.
365	A. B. Hancock	1	4	5	1896	7-inch pipe	1,170		56		Hard	12 wind	125	100	Small.	Dom; etc.
366	do	1	4	5	1882	7-inch pipe	1,169		56		do	do				Dom; etc.
367	D. W. White	1 N. W.	4	4	1871	7-inch pipe	1,109	1,089	195			Gas; centrifugal; 8 wind.	1,200	200	0.400	Irr; dom.
368	W. F. Holcomb	1 S. W.	4	33		7-inch pipe	1,115	1,089	37		Soft				Small.	Dom.
369	Alex. Wixom	1 N. W.	4	4	1899	8-inch pipe	1,117		45		Hard	12 wind	50	148	Small.	Dom.
370	F. L. Holcomb	1	4	33	1885	7-inch pipe	1,128	1,100	47		do	do	100	150	Small.	Dom.
371	do	1 S. W.	4	33	1885	7-inch pipe	1,133	1,103	47		do	do	100	150	Small.	St.
372	J. J. Whitney	1	4	4	1884	Pipe	1,129	1,101	112		do	Wind		400	Small.	Dom; st.
373	P. B. Hockaday	1	4	4	1887	7-inch pipe	1,133		110		Soft	12 wind		500	Small.	Dom; irr.
374	J. J. Morris, sr	1	4	5	1890	8-inch pipe	1,137	1,109	53		do	10 wind		75	Small.	Dom; irr

[a] Tools left in well.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).	Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S. W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
375	Dexter Field	1 4 5	1870	6-inch pipe	1,147	1,112	45		Hard	10 wind			Small.	Dom.
		N. W.												
376	C. A. Muscott	1 4 32	1886	8-inch pipe	1,158	1,115	78		Soft	12 wind	$100	$250		Dom; irr.
377	J. W. Roberts	1 4 27	1899	10-inch pipe	1,210	1,155	160	GC	do	Plunger pump; 5 electric.	400	900	0.24	Dom; irr.
378	T. C. Parker	1 4 32	1886	Pipe	1,205		98		Hard	12 wind; 3 gas		550		Dom; irr.
379	P. Oldecker	1 4 33	1893	7-inch pipe	1,195		133		do	Geared pump; 2 gas.		400	0.10	Dom; irr.
380	A. Peterson	1 4 33	1890	7-inch pipe	1,192	1,134	76	SG	Soft	12 wind	50	100	Small.	Dom; irr.
381	C. A. Bruckman	1 4 32	1894	10-inch pipe	1,221	1,151	146		do	Geared pump; 16 gas.	325	775	0.36	Irr.
382	do	1 4 32	1892	7-inch pipe	1,215	1,145	84	SCG	do	12 wind	115	300		Irr.
383	do	1 4 32	1892	7-inch pipe	1,214	1,144	85		do	Geared pump; 5 gas.	115	625	0.042	Irr.
384	do	1 4 32	1890	7-inch pipe	1,192	1,134	85		do	12 wind	115	250	Small.	Dom.
385	Wilson & Wheat	1 4 32	1890	7-inch pipe	1,188	1,128	82		do	16 wind				Dom; irr.
386	E. D. Palmer	1 4 33	1894	7-inch pipe	1,184		80		Hard	14 wind			Small.	Dom; irr.
387	C. G. Leonhardt	1 4 32	1890	7-inch pipe	1,182		85		Soft	12 wind	115	192	Small.	Dom; irr.
388	do	1 4 32	1899	8-inch pipe	1,197	1,133	90		do	do	125	297	0.006	Irr.
389	S. E. A. Palmer	1 4 33	1887	7-inch pipe	1,176	1,124	92		Hard	14 wind	150	350	0.003	Dom; irr.
390	Fred F. Palmer	1 4 33	1899	D, 4 by 6 feet; 7-inch pipe	1,189	1,134	85		do	Duplex; steam	300	500	0.036	Irr.
391	W. D. Wilson	1 4 32	1893	8-inch pipe	1,203	1,138	94		do	12 wind				Irr.
392	S. H. Harmon	1 4 32	1893	10-inch pipe	1,194	1,132	133		do	Geared pump; 5 gas.	1,300	(a)	0.020	Irr.
393	S. W. Harmon	1 4 32	1882	7-inch pipe	1,181	1,128	75		do	12 wind	50	220		Dom; irr.
394	J. O. Slatter	1 4 33	1890	7-inch pipe	1,155		100		Soft	do		150	Small.	Dom.
395	C. N. Damron	1 4 33		7-inch pipe	1,120	1,093	47		Hard	8 wind			Small.	Dom.
396	Mrs. Amy McCrary	1 4 33	1899		1,138	1,112	91		Soft	Hand			Small.	Dom.
397	Thos. Webster	1 4 33	1898	7-inch pipe	1,134					12 wind				Dom.
398	N. M. Swarthout	1 4 33	1885	7-inch pipe	1,142	1,115	75		Hard	8 wind	150	100	Small.	Dom.
399	do	1 4 33	1895	10-inch pipe	1,169		80			Horse	100	35	Small.	Irr.
400	J. H. Lytle	1 4 33	1885	7-inch pipe	1,166	1,135	79		Hard	12 wind	75	50	Small.	Dom; irr.
401	H. S. Davidson	1 4 33	1880	7-inch pipe	1,158		56		Hard	do		500		Dom; irr.
402	N. Swarthout	1 4 33	1885	7-inch pipe	1,142	1,108	55		do	8 wind			Small.	Dom.
403	G. W. Evans	1 4 33	1887	6-inch pipe	1,128	1,096	75		do	do			Small.	Dom.
404	R. M. Bradley	1 4 33	1884	7-inch pipe	1,101	1,082	90			12 wind			Small.	Dom.
405	Mrs. Sarah Abel	1 4 33	1880	D, 3 feet dia	1,109	1,088	22		Soft	Bucket			Small.	Dom.
406	R. Poppett	1 4 34	1885	7-inch pipe	1,109	1,085	45			12 wind	50	140	Small.	Dom; irr.
407	G. Johnson	1 4 34	1890	7-inch pipe	1,114	1,087	47		Hard	8 wind	60	60	Small.	Dom; irr.
408	E. G. Fish	1 4 34	1889	2-inch pipe	1,133		425		do	do	1,000		Small.	Dom; irr.
409	C. Cohn	1 4 34		7-inch pipe	1,118	1,089			Soft	10 wind			Small.	Dom.
410	O. B. Peck	1 4 34	1888	7-inch pipe	1,147		115		do	14 wind			Small.	Dom; irr.
411	K. P. Stephens	1 4 34	1883	7-inch pipe	1,164	1,114	65		do	do			0.003	Dom; irr.

412	Jno. Y. Anderson	1	4	34	1900	8-inch pipe 12-inch pipe	1,165	1,109	150 460				2,000			Not used.
413	Jno. Lawrence	1	4	34	1897	7-inch pipe	1,091	1,076	42		Soft	8 wind		160	Small.	Dom.
414	J. C. Wees	1	4	34	1898	7-inch pipe	1,097	1,073	46		do	do				Dom.
415	Thos. J. Remnous	1	4	34	1900	7-inch pipe	1,133	1,101	72		do	10 wind	72	150	Small.	Dom; irr.
416	H. H. Ham	1	4	34	1888	7-inch pipe	1,121	1,090	52		Hard	8 wind	75	100	Small.	Dom; irr.
417	W. M. Jenkins	1	4	34	1884	7-inch pipe	1,118	1,088	52			12 wind			Small.	Dom; irr.
418	Oscar Wees	1	4	34	1885	7-inch pipe	1,108		48		Soft	8 wind			Small.	Dom.
419	M. W. Davis	1	4	34	1898	7-inch pipe	1,100		42		do	do	40	90		Dom.
420	P. W. Heap, jr	1	4	34	1894	7-inch pipe	1,128	1,088	58		do	12 wind	60	125	0.002	Dom; irr.
421	B. M. Wall	1	4	34	1897	3-inch pipe	1,100		137		Hard	8 wind			Small.	Dom; irr.
		S.	W.													
422	E. Case	1	4	3	1899	8-inch pipe	1,086	1,073	50		Soft	Hand			Small.	Dom.
423	Jno. E. Garner	1	4	2	1900	8-inch pipe	1,087	1,073	334			Centrifugal; 8 gas	750	750	0.800	Irr; etc.
		N.	W.													
424	do	1	4	35	1888	10-inch pipe 7-inch pipe	1,164	1,108	420		Hard	Centrifugal; 20 electric.	1,500	3,000	1.200	Irr.
425	Colton City Water Co.	1	4	31	1900	10-inch pipe	1,202		208			Centrifugal; 25 gas			1.480	Irr; dom.
426	San Bernardino City Waterworks.	1	5	36	1895 1900	2 11-inch pipes 12-inch pipe	1,239	1,207	320 550 800		Soft	Centrifugal; 25 gas			1.400	City supply.
427	Riverside-Highland Water Co.	1	4	31	1900	10-inch pipe	1,218	1,204	320							Not used.
428	do	1	5	36	1892	10-inch pipe	1,246	1,211	650			Centrifugal; 22 gas	5,000	1,100	1.600	Irr; dom.
429	do	1	4	31	1893	2 10-inch pipes	1,250	1,201	350 300			Centrifugal; 30 electric.	3,000	2,500	2.000	Irr; dom.
430	do	1	4	31		2 10-inch pipes	1,258	1,203	500-600			do	3,000	2,500	2.800	Irr; dom.
431	Rialto Irrig. Dist Citizens' Water Co	1	5	36	1891	2 10-inch pipes	1,255	1,204	450		Hard	Centrifugal; turbine	1,500		1.300	Irr; dom.
432	do	1	5	36	1894	10-inch pipe	1,260	1,207	460			Centrifugal; 20 gas	1,800	6,000	0.720	Irr; dom.
433	F. E. Watkins	1	5	36	1888	10-inch pipe	1,266	1,210	621		Soft	2 25 compressors			0.890	Irr.
434	Lytle Creek Water and Imp. Co.	1	5	36	1900	3 12-inch pipes	1,290	1,215	226	Gravel	do	Duplex steam	3,661	3,500	[b]2.200	Irr.
435	Rialto Irrig. Dist	1	5	25	1897	10-inch pipe	1,333	1,303	520			Centrifugal; 30 electric.	1,500	2,000	1.800	Irr; dom.
436	do	1	5	25	1894	10-inch pipe	1,342	1,306	432		Hard	do	1,500	2,000	1.500	Irr; dom.
437	Anglo-American Canaigre Co.	1	5	25	1899	D, 7 by 9 feet (2)	1,337	1,307	45							Not used.
438	F. E. Watkins	1	5	25	1898	10-inch pipe	1,390	1,251	381				2,000			Not used.
439	Riverside-Highland Water Co.	1	4	31		20 wells	1,200-1,225								([c])	Irr.
		S.	W.													
440		1	4	4		D, 4 by 4 feet	1,089	1,083	7			Hand				Stock.
441	M. E. Brooks	1	4	5	1886	3-inch pipe	1,102		132		Hard	8 wind				Dom; st; irr.
442	do	1	4	5		3-inch pipe	1,105		140			12 wind			Small.	Irr.
443	Mrs. Mary Bemis	1	4	5	1888	Pipe	1,113		132		Hard	Hand			Small.	Dom.
444	A. W. Bemis	1	4	5	1890	8-inch pipe	1,118	1,101	48		Soft	12 wind			Small.	Dom.
445	do	1	4	5	1894	10-inch pipe	1,114	1,104	50			Centrifugal; 3 gas		250	0.014	Irr.
446	D. F. Probst	1	4	4	1886	7-inch pipe	1,085	1,070	36		Soft	10 wind			Small.	Dom.
447	Mrs. A. Tompkins	1	4	5	1882	7-inch pipe	1,115		212		do	Wind	1,000	175	Small.	Dom; irr.

[a] Included in cost of well.

[b] Two wells.

[c] These 20 wells have nearly all ceased flowing.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner of well.	Location (T. R. S.).			Year completed.	Class of well.	Elevation of surface.	Elevation of water.	Depth of well.	Strata.	Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
		S.	R.	W.			*Feet.*	*Feet.*	*Feet.*						*Sec.-ft.*	
448	J. Hancock	1	4	5	1875	7-inch pipe	1,138	1,092	128		Hard	Wind			Small.	Dom; irr.
449	M. D. Reynolds	1	4	5	1900	10-inch pipe	1,136	1,106	146		Soft	Centrifugal; 25 gas	$300	$1,400	0.027	Irr.
450	do	1	4	5	1898	7-inch pipe	1,116	1,094	40		do	8 wind	60	150	Small.	Dom.
451	Mrs. M. Lord	1	4	4	1888	3-inch pipe	1,125		150		Hard	10 wind			Small.	Dom.
452	John Marshall	1	4	5	1888	7-inch pipe	1,128	1,103	42		Soft	do			Small.	Dom.
453	I. W. Hazlett	1	4	4	1900	7-inch pipe	1,101	1,082	142		Hard	12 wind	233		0.002	Dom.
454	Mrs. Alice Wixom	1	4	4		7-inch pipe	1,067	1,055	22		Soft	do			Small.	Dom.
455	Mrs. Irving	1	4	4		7-inch pipe	1,099	1,078	100			8 wind			Small.	Dom.
456	J. B. Kitring and R. H. Hacker.	1	4	4	1895	2-inch pipe	1,085	1,070 in 1899.	152		Hard	do		260	Small.	Dom.
457	J. F. Cadd	1	4	4	1888	7-inch pipe	1,068	1,057	40		do	Hand	40		Small.	Dom.
458	H. E. Gardner	1	4	5		3-inch pipe	1,089	1,075			Soft	8 wind			Small.	Dom.
459	Mrs. Marilla Smith	1	4	5	1889	2-inch pipe	1,094	1,079	122		do	Wind	122	150	Small.	Dom.
460	San Bernardino County Hospital.	1	4	8	1898 1899	3-inch pipe 7-inch pipe 10-inch pipe	1,089	1,071	125 125 330		do	Centrifugal; 6 gas			0.300	Irr.
461		1	4	8		2 wells	1,057					Electric				Irr.
462	Riverside Trust Co	1	4	26		9 wells	1,019	1,019				Artesian				Irr.
463	Riverside Water Co	1	4	2			1,036	1,036				do			1.976	Irr.
464	do	1	4	2			1,037	1,037				do			1.930	Irr.
465	do	1	4	2	1900	10-inch pipe	1,040	1,040	544			do			2.896	Irr.
466	do	1	4	2	1900	10-inch pipe	1,041	1,041	582	CSG		do			3.096	Irr.
467	E. D. Meissner	1	4	26	1899	10-inch pipe 8-inch pipe	1,200	1,120	500	GC		Plunger pump; 20 gas	2,600	1,350	0.200	Irr.
468	G. G. Lathrop	1	4	26	1897	7-inch pipe	1,063	1,017	70	GC	Hard	10 wind	105	130	0.003	Dom; irr.
469	R. L. Dewitt	1	4	26	1897	Dug	1,047	1,028	26	LC	do	Hand				Dom.
470	Charles Morris	1	4	25	1892	D, 12 by 12 feet, 10-inch pipe.	1,078	1,063	80	SGC	do	12 wind	400	140	0.007	Irr.
471	do	1	4	26	1899	10-inch pipe 8-inch pipe 7-inch pipe	1,077		640	SGC	do	Artesian	1,500		0.005	
472	No record															
473	F. S. Waters	1	4	23	1877	2-inch pipe	1,054	1,044	196		Hard	8 wind	200	145	0.002	Dom; irr.
474	J. H. Hatherley	1	4	23	1888	3-inch pipe	1,555		450			Artesian	1,700		0.140	Irr.
475	J. H. Kelly	1	4	23	1890	8-inch pipe	1,089		382		Hard	do	2,000		0.400	Dom; irr.
476	do	1	4	23	1891	7-inch pipe	1,074	1,066	500		do	Hand		5		Dom.
477	Mr. Myers	1	4	25	1890	7-inch pipe	1,060		400		do				[a]	
478	W. E. Pedley	1	4	2	1899	10-inch pipe	1,042		510	GR	Soft	Artesian	1,284		2.700	Irr.

[a] Stopped flowing in 1899.

MANUFACTURE OF PORTLAND CEMENT IN SOUTHERN CALIFORNIA.

An important element in the development of an irrigation community is the cost and use of hydraulic cement. Prior to 1893 all of the cement used in southern California came from Europe. This meant a serious financial drain on this section, and the building of a cement-manufacturing plant near Colton which reduced the cost of Portland cement 25 per cent and also kept the remaining 75 per cent at home was therefore an important event in irrigation development as well as building.

The plant of the California Portland Cement Company is three-fourths of a mile from the town of Colton. The company manufactures Portland cement, lime, marble dust, and crushed rock. It employs 70 men, and the capacity of the plant is 300 barrels of cement or 500 barrels of lime daily and an unlimited output of crushed rock. This Portland cement has been extensively used in the various irrigation and hydraulic-power systems of southern California, and has been pronounced by engineers to be equal to imported cement, while it is sold at a much lower price than the foreign article. C. W. Smith, of Pasadena, is now the president of the company and E. Duryee is the chemist.

Probably few, even in the engineering profession, would be inclined to credit the statement, which nevertheless can be corroborated by United States Government reports, that 75 per cent of the Portland cement consumed in the United States during 1900 was manufactured in this country. The only Portland-cement plant on the Pacific coast, however, is the one at Colton, where rotary kilns are in operation. At the outset the Colton company employed an expert to investigate the cement works in the East, of which there are many, and they adopted, as the result of his investigations, what they believe to be the best process. The plant is continuous and largely automatic in operation, machinery being employed to such an extent that 3 barrels of cement per day are obtained for each man employed, as contrasted with 1 barrel per day per man, the ordinary output in European works. The process is protected by letters patent and is American in every respect. The works are very favorably located, being in the center of the semitropical fruit belt of southern California and contiguous to most of the extensive irrigation and hydraulic-power plants of that section, thus insuring an increasing market for the product in the future. In the rear of the mill towers Slover Mountain, with its inexhaustible deposit of pure calcspar and two clay deposits at short distances, which provide abundant crude materials. The company is fortunate in having available limestone almost chemically pure and a clay peculiarly adapted to the manufacture of the cement, while the Los Angeles petroleum provides a cheap and excellent fuel. These advantages

enable the company to manufacture its product at a minimum cost and to place it on the market for about three-fourths the price of foreign cements. The mixing, grinding, and burning of the crude materials is carried on under the constant direction and analysis of a chemist whose laboratory is at the works. The crude materials are first crushed and mixed by weight, then ground to an impalpably fine powder, then fed continuously at the rate of 3 tons hourly into a rotary kiln 75 feet long, in which they remain one and three-fourths hours. The low heat of the upper end of the kiln drives off the moisture from the raw mixture; the low red heat of the middle part decarbonizes the limestone; and the high heat of the lower end causes the caustic lime alumina and silica to unite and form Portland cement clinker—little nodules the size of beans and walnuts. After leaving the kiln the clinker is cooled and ground into the finished product. The materials enter the kiln as a mechanical mixture of limestone and clay and come from it a chemical compound of definite formulæ.

The character of the Colton cement is the same as that of all Portland cements. Analyzed it approximates some of the leading foreign brands, while the physical tests have generally shown it to be superior to the foreign brands in the local market both in the fineness of the powder and in its tensile strength.

Analyses of Portland cements.

Constituent.	Colton, American (E. Duryee, analyst).	White Bros., English (E. Duryee, analyst).	Alsens, German (W. MacClay, analyst).
	Per cent.	*Per cent.*	*Per cent.*
Silica (SiO_2)	22.060	23.567	24.90
Alumina (Al_2O_3)	9.310	10.020	11.22
Ferric oxide (Fe_2O_3)	3.090	3.080	
Magnesia (MgO)	0.900	1.067	0.38
Lime (CaO)	61.512	59.000	59.98
Sulphuric acid (SO_3)	1.200	1.400	0.86
Alkalies	1.761	2.100	0 50
Moisture and carbonic acid			2.16
Total	99.833	100.234	100.00

The following table comprises data from the report of Mr. J. W. Robinette, C. E., the cement tester, who sampled and tested 4,000 barrels of the product purchased by the San Gabriel Electric Company:

Results of tests of Colton Portland cement.

Length of time.	Number of tests.	Average tensile strength.	Fineness passed.	Average of 4,000 barrels.
		Pounds.	*Mesh.*	*Per cent.*
1 day	255	129	2,500	99.64
7 days	510	510	8,100	95.33
28 days	481	607	144,000	93.22

The extreme care taken to insure a good and uniform cement may be inferred from the fact that the raw mixture is every half hour subjected to chemical tests for the determination of the percentage of lime, which element is not permitted to vary either way more than 1 per cent from the standard. The mixture is ground so fine that only one-third of 1 per cent remains on a 50-mesh screen, 5 per cent on a 90-mesh screen, and 7 per cent on a 120-mesh screen. After it has been burned the clinker is spread in layers on a cooling and mixing floor, and the accumulated burn of several days is thoroughly mixed before it is ground. After the cement has been ground and again mixed in conveyers and elevators it is put into sacks holding 95 pounds each. A sample is taken from every tenth sack and numbered. These samples are tested, a record of the tests being kept and embodied in the reports which are mailed to the purchasers.

ACKNOWLEDGMENTS.

In the preparation of this report on the water systems of San Bernardino Valley, involving as it does numerous historical references, many authorities were consulted. The writer is particularly indebted to Mr. Kingsbury Sanborn, chief engineer of the Riverside Water Company, who rendered valuable assistance in the determination of the total output from the gravel beds above Colton and who assisted in many other ways, and to Mr. William Irving, who furnished nearly all of the data concerning the Gage canal and who assisted generally. Acknowledgments are also due to many other engineers familiar with local conditions.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground water," by F. H. King, and one on "Theoretical investigation of the motion of ground waters," by C. S. Slichter.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

1901.

Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part IV, Hydrography, 1901; octavo, 768 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton; and "The High Plains and their utilization," by W. D. Johnson.

Correspondence should be addressed to

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United States Geological Survey,
Washington, D. C.

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Underground waters of southeastern Nebraska, by N. H. Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.

15, 16. Operations at river stations, 1897, Parts I, II, 1898.

17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of Bighorn Mountains, by Elwood Mead, 1899.

24, 25. Water resources of the State of New York, Parts I, II, by G. W. Rafter, 1899.

26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.

27, 28. Operations at river stations, 1898, Parts I, II, 1899.

29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Puerto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.
34. Geology and water resources of southeastern S. Dak., by J. E. Todd, 1900.

35-39. Operations at river stations, 1899, Parts I-V, 1900.

40. The Austin dam, by Thomas U. Taylor, 1900.

41, 42. The windmill: its efficiency and use, Parts I, II, by E. C. Murphy, 1901.

43. Conveyance of water in irrigation canals, etc., by Samuel Fortier, 1901.
44. Profiles of rivers, by Henry Gannett, 1901.
45. Water storage on Cache Creek, California, by Albert E. Chandler, 1901.
46. Reconn. of Kern and Yuba rivers, Cal., by F. H. Olmsted and M. Manson, 1901.

47-52. Operations at river stations, 1900, Parts I-VI, 1901.

53, 54. Geology and water resources Nez Perce Co., Idaho, Pts. I, II, by I. C. Russell.

55. Geology and water resources portion of Yakima Co., Wash., by G. O. Smith.
56. Methods of stream measurement, 1901.
57. Deep borings in United States, Pt. I, by N. H. Darton, 1902.
58. Water storage on Kings River, California, by J. B. Lippincott, 1902.

59, 60. Development and application of water in southern California, Pts. I, II, by J. B. Lippincott, 1902.

Other papers are in preparation. These pamphlets will be sent to persons who have assisted in their preparation by replies to inquiries or otherwise. Requests made for a certain paper are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent. Application should be made either to members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 61

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES
PART II (NEBRASKA-WYOMING).—DARTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 61

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

PRELIMINARY LIST

OF

DEEP BORINGS IN THE UNITED STATES

PART II

(NEBRASKA-WYOMING)

BY

N. H. DARTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., November 27, 1901.

SIR: I have the honor to transmit herewith Part II of a preliminary list of deep borings in the United States (400 feet or more in depth), by Mr. N. H. Darton, with the request that it be published in the series of Water-Supply and Irrigation Papers. Part I is in type as Paper No. 57. It has been found necessary to divide the whole into two papers, because of the statutory limit of 100 pages for these papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES.

PART II.—NEBRASKA-WYOMING.

By N. H. Darton.

INTRODUCTION.

The wells and borings reported in the paper are all more than 400 feet in depth. The information concerning them has been obtained partly from replies to circular letters sent to all parts of the United States and partly from geological reports and other published sources. Owing to the difficulty of obtaining replies to the circulars, to lack of knowledge on the part of correspondents, and to the incompleteness of published records, doubtless there are borings which have not been reported. In regions of oil and gas wells, where borings are numerous, the individual wells can not be listed here, but representative wells are given. References to logs or records of the wells, or extended descriptions of them, are given in footnotes, and after the list of wells in each State there is added a list of the principal publications relating to deep borings in that State.

The bearing of the information given in the columns of the lists probably is apparent, unless, perhaps, in the one headed "Height to which the water rises." In this column an entry such as "—45" indicates that the water rises to within 45 feet of the surface; "+45" indicates that it is a flowing well and has sufficient head to raise the water 45 feet above the surface in an open pipe 45 feet or more in height. The yield in gallons per minute usually is estimated. Depths and diameters often have been reported from memory, and different sources of publication sometimes give different figures. Most wells which are not stated to be "for oil," "for gas," "brine," "abandoned," etc., in the remarks column, or "not any" in the yield column, generally afford more or less water. Many of the gas and oil wells, active or abandoned, yield salt water.

NEBRASKA.

(Arranged by counties.)

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Hastings[1]	Adams	1,145			—40	Salt water at 940 feet.
Harrisburg	Banner	400-790				Several unsuccessful borings.
T. 34, R. 8, sec. —	Boyd	760	3	100	Flows.	
T. 33, R. 8, sec. 18	do	760	3	420	Flows.	
Kearney	Buffalo	2,460(?)				Unsuccessful.
T. 10, R. 13, sec. 34	Cass	480	3			Water at 30 feet.
Do	do	500	4			Water at 470 feet.
St. Helena[2]	Cedar	466		Many.	Flows.	Water at 400 feet.
T. 32, R. 33, sec. 23	do	400	2	30	Flows.	
T. 32, R. 23, sec. 24	do	448	2	30	Flows.	Water at 248 feet.
T. 31, R. 23, sec. 11	do	600	2		Flows.	Water at 340 feet.
T. 33, R. 13, sec. 35	do	600	2		Flows.	Water at 600 feet.
T. —, R. —, sec. —	do	602	2	25	Flows.	Water at 550 feet.
T. —, R. —, sec. 10	do	481	2		Flows.	
T. 32, R. 23, sec. —	do	445	2		Flows.	Water at 398 feet.
T. 6, R. 39, sec. 21	Chase	500	2			Water at 22 feet.
Cliff	Custer	400-485	3½-1¼	Many.	No flow.	Several wells.
Chadron	Dawes	100, 1,100, and 1,800				Three wells; no water.
T. 31, R. 5, sec. 5	Dixon	407	2	60	Flows.	
T. 31, R. 6, sec. 20	do	484	3		Many.	Water at 18 feet; supply unlimited.
Omaha (Clark and Sixteenth streets)	Douglas	664		125	+52	Temp. 58°.
Omaha (Grant smelter).	do	1,044	10-6	800	+65	Flows at 650 and 800 feet also; temp. 55°.
Omaha (Thirty-second and O streets).	do	1,800		Many.	—70	
Omaha (Elmwood Park).	do	1,845			—50	
Omaha (Hanscom Park).	do	1,120		Many.	—138	
Omaha (Riverview Park).	do	1,065		600		Temp. 62°.
Omaha (Willow Spring).	do	1,700		Many.	+100	
Omaha (Exposition grounds).	do	1,115		Many.	Flows.	First water at 700 feet; temp. 60°.
Omaha (Seymour Park).	do	1,303		500	+35	
Omaha (Pickards)	do	1,383		70	Flows.	Temp. 62°; abandoned.
Omaha (Krug brewery).	do	1,316		Many.	—142	
Omaha (Power house, Nineteenth street).	do	840				
Omaha (Cortland Beach).	do	998	6-5		+40(?)	
Farm of G. E. Hawkins.	Gage	1,260	6		Flows.	
Beatrice	do	1,200		Few.	Flows.	
Farm of W. E. Robertson.	do	1,240	6		Flows.	Water at 50 feet.
Hyannis	Grant	+400				Two wells.
O'Neill	Holt	1,300				Unsuccessful.
Farm of E. Demerit	Hooker	1,200			Flows.	
Dannebrog[3]	Howard	1,011				Do.
T. 2, R. 2, sec. 4	Jefferson	500	4		+½	Seven borings for coal; strong salt water at 225-238 feet; temp. 70°.
T. 13, R. 35, sec. 5	Keith	525	6	500		Water at 7 feet.
T. 14, R. 41, sec. 2	do	407	3½	2		Water at 385 feet.
T. 12, R. 37, sec. 8	do					Water at 176 and 305 feet; 137 feet of water in well.
T. 9, R. 8, sec. 29	Kimball	460		Many.	No flow.	
T. 32, R. 6, sec. 16	Knox	656	8	Many.	Flows.	Water at 625 feet.
T. 33, R. 8, sec. 18	do	770	3		Flows.	Water at 740 feet.
T. 33, R. 3, sec. 13	do	504	2	90	Flows.	Water at 482 feet.
T. 32, R. 6, sec. 8	do	600	2	280	Flows.	Water at 435 feet.
T. 32, R. 6, sec. 16	do	656	8	2,500	Flows.	Water at 575 feet.
T. 32, R. 6, sec. 16	do	656	8	2,500	Flows.	Water at 600 feet.
T. 32, R. 6, sec. 16	do	630	8		Flows.	

[1] Record, U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 12, pp. 37-38.
[2] Record, Am Assoc. Adv. Science, Proc., vol. 35, 1886, pp. 217-219
[3] Record, U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 12, p. 47.

NEBRASKA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
T. 32, R. 2, sec. 17	Knox	420		50		
Santee Agency Mission.[1]	do	603	2½	20		
Lincoln (sanitarium).[2]	Lancaster	570				
Lincoln[3]	do	985			−100	Salt water at 244 and 544 feet.
Lincoln (Burlington Beach).	do	2,463		Many.	Flows.	Salt water.
Lincoln (public square).	do	1,050		Many.	Flows.	Salt water at 560 feet and 1,050 feet.
Tilden	Madison	400+	4		−90	
Norfolk	do	472			−100	
Brownville[4]	Nemaha	1,001				
Nebraska City	Otoe	448	4	½	+6	Mineral water.
Do	do	1,000–1,200				Several deep wells in progress.
Do	do	570				Salt water.
Dubois	Pawnee	562	6			Unsuccessful.
McCook	Redwillow	400	8			Some water at 375 feet.
Falls City	Richardson	1,300				
Rulo (2 miles west)	do	1,370				Coal prospect.
Seward[5]	Seward	610			No flow.	Abandoned.
Gordon	Sheridan	580				Failure; water at 180–182 feet.
York[6]	York	590			+16	
Ericson	Wheeler	(?)				Failure.

[1] Record, 51st Cong., 1st sess., Senate Ex. Doc. No. 222, pl. op. p. 55.
[2] Descriptions, records, etc., U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 12, pp. 28–30; Am. Assn. Av. Science, Proc., vol. 35, p. 218; Physical Geography and Geology of Nebraska (Aughey), 1880.
[3] Record, Am. Assoc. Adv. Science, Proc., vol. 35, p. 218.
[4] Am. Assoc. Adv. Science, Proc., vol. 35, pp. 217–219.
[5] Record, U. S. Geol. Survey, Water-Supply and Irrigation Paper No. 12, p. 31.
[6] Ibid., pp. 33–34.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN NEBRASKA.

Underground Waters of a Portion of Southeastern Nebraska, by N. H. Darton, United States Geological Survey, Water-Supply and Irrigation Paper No. 12, 56 pages, maps, plates, Washington, 1898.

A Preliminary Report on the Geology and Water Resources of Nebraska west of the one hundred and third meridian, by N. H. Darton. United States Geological Survey, Eighteenth Annual Report, 1896–1897, part 4, pages 719–785, Washington, 1899.

NEVADA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Battle Mountain[1]	Lander	800	6			Strong flow.
Do.[2]	do	650		58		Several flows at less depths.
Dalamar	Lincoln	800				Unsuccessful.
——[3]	Ormsby	400	6–7	5		Several wells.
Ely	White Pine	600		Several.		
Sierra Valley[4]	(?)	1,132	3	30		Hot water.
Vail Ranch	Churchill	400			No flow.	

[1] Nevada, Report Surveyor-General and State Land Register, 1891–92, p. 72.
[2] Ibid., 1889–90, p. 82.
[3] Ibid., 1891–92, p. 72.
[4] Ibid., 1889–90, p. 82.

NEW HAMPSHIRE.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Dover	Strafford	400	6	100	No flow.	
Concord	Merrimac	1,325	6	Few.	—16	Well abandoned; water at 935 feet.
Manchester	Hillsboro	630	8	Few.	No flow.	

NEW JERSEY.

Allenhurst [1]	Monmouth	530			Flows.	
Do	do	545			Flows.	
Asbury Park [2]	do	448	8	65¼	Flows.	Good water; temp. 60°.
Do	do	800			Flows.	
Do	do	1,130-1,045	6	1,000	Flow.	Two wells.
Do. [3]	do	1,330			Flows.	
Atlantic City [4]	Atlantic	578	8		Flows.	Water at intervals from 328 to 554 feet.
Do	do	809	6		Flows.	
Do	do	1,150	8-6		+5	No water 960-1,120 feet.
Do	do	960	6-4½		Flows.	Pumps 200 gallons.
Do	do	554	8	50	Flows.	
Do	do	735	6-4½		Flows.	Do.
Do	do	720	6		Flows.	Pumps 250 gallons.
Do	do	780	6-4½	150	Flows.	
Do	do	763	8	Many.	Flows.	
Do	do					
Do	do	1,398	10-4½			No water at this depth. Several flows above.
Do	do	805	8-4½	40	Flows.	Pumps 125 gallons.
Do	do	843	6	100	Flows.	
Do	do	813	6	105	Flows.	Pumps 400 gallons; temp. 66°.
Do. [5]	do	1,400	10-4			No water at this depth. Several flows above.
Atlantic Highlands	Monmouth	480	4½	250	Flows.	
Avalon [6]	Cape May	925	10-4½	75	8	
Avon Inn [7]	Monmouth	430	3	52	Flows.	
Bayhead	Ocean	710			Flows.	
Do	do	885			Flows.	
Bayhead (1 mile north). [8]	do	813	4½-3	85	Flows.	
Barnegat Park [9]	do	670			Flows.	
Bayonne	Hudson	600		Few.		
Beach Haven [10]	Ocean	430	3	10	Flows.	
Do. [8]	do	575	8	125	Flows.	
Belmar [9]	Monmouth	445-480			Flow.	Four wells.
Do	do	640-660			Flow.	Two wells.
Berkeley Arms [11]	Ocean	475		60	To surface.	
Bernardsville	Somerset	621		3½		
Brigantine [12]	Atlantic	798	6	100	Flows.	
Brookdale [13]	Essex	712	4½	174		
Burlington		675				
Cape May Point [14]	Cape May	456				Unfinished.
Crab Island		520	3		Flows.	
Columbus [15]	Burlington	715				
Daretown [16]	Salem	405			—100	
Dealbeach	Monmouth	500-525	6		Flow.	Two wells.

[1] Record, etc., New Jersey Geol. Surv., Report for 1893, pp. 413-414.
[2] Record, New Jersey Geol. Surv., Reports for 1883, p. 20; 1884, p. 124; 1885, p. 129.
[3] Record, etc., New Jersey Geol. Surv., Report for 1895, pp. 72-74.
[4] Records, etc., of many wells at Atlantic City. New Jersey Geol. Surv., Reports for 1887, 1888, 1889, 1892, 1893, 1894, 1895, 1896, 1897, 1898, and 1899.
[5] Record, New Jersey Geol. Surv., Report for 1890, p. 90.
[6] Record, New Jersey Geol. Surv., Report 1898, pp. 78-82.
[7] Record, etc., New Jersey Geol. Surv., Report for 1885, p. 130.
[8] Record, etc., New Jersey Geol. Surv., Report for 1893, pp. 394-396; 1896, p. 152.
[9] Records, etc., New Jersey Geol. Surv., Report for 1896, p. 154.
[10] Record, etc., New Jersey Geol. Surv., Report for 1890, p. 266; 1893, pp. 394-396.
[11] Record, etc., New Jersey Geol. Surv., Report for 1884, p. 127; 1885, p. 133.
[12] Record, etc., New Jersey Geol. Surv., Report for 1895, pp. 77-79.
[13] Record, etc., New Jersey Geol. Surv., Report for 1897, pp. 227-229
[14] Record, etc., New Jersey Geol. Surv., Report for 1885, p. 140.
[15] Record, etc., New Jersey Geol. Surv., Report for 1892, pp. 305-306.
[16] Record, etc., New Jersey Geol. Surv., Report for 1897, pp. 250-253.

NEW JERSEY—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Farmingdale [1]	Monmouth	730				Water from 530 feet.
Flemington	Hunterdon	405		107	−161	
Fort Lee		1,000				Through trap into shale. No water.
Franklin [2]	Essex	400	8	125		
Greenwich [3]	Cumberland	690	4–2½			No water found.
Glassboro [4]	Gloucester	511				
Harrisonville [5]	do	402				
Harvey Cedars	Ocean	500	4	100	Flows.	
Do.[6]	do	500	4½	120	+6	
Hazlet [7]	Monmouth	577	8–4½			
Hightstown [8]	Mercer	428–500		Many.		
Hoboken [9]	Hudson	400				Bored in 1828. Rock at 40 feet
Holmdel [10]	Monmouth	601	8–4		Flows.	
Jamesburg [11]	Middlesex	481	8–6	52		
Jersey City (Limbeck's brewery).[12]	Hudson	776½	8	33		
Jersey City (Malone & Co.).	do	500		50		
Jersey City (Stock Yards).[13]	do	455	8–6½			
Jersey City (Communipaw).	do	500				Salt water.
Jersey City (Sugar Refinery).[12]	do	1,000	8–4	50		
Jersey City (Cox's brewery).[12]	do	400	5	Few.		
Jersey City (Dixon Co.).	do	1,205		22		
Jersey City (Colgate & Co.).	do	1,500		15		Rock 35–1,500 feet.
Jersey City (Hudson Canal Co.).	do	650		Few.		
Jersey City (Traction Co.).	do	2,200				No water.
Jersey City (Mehl & Co.).[14]	do	1,007		150		
Jersey City (Coal dock).[15]	do	450				Brackish water.
Jobstown.[16]	Burlington	715				
Kearney	Union	600		50		
Lake Como [17]	Monmouth	535			Flows.	
Lakewood [18]	Ocean	475		3½	+17	
Do.[19]	do	600–625	6	100	+200	Several wells.
Loch Arbor		562			Flows.	
Longport [20]	Atlantic	803	6	180	Flows.	Temp. 66°
Mantoloking	Ocean	790		25	+33	
Do.[21]	do	922		60	+42	
Moorestown [22]	Burlington	457				
Morristown (2 miles west).	Morris	438	6	2½	−60	
Mount Holly	Burlington	675				Impure water.
Montclair (Mount Prospect).	Essex	510	7¾	45		Soft water.
Newark (Balentine's)	do	529		150		
Newark (Celluloid Co.).	do	827	10	200	No flow.	
Newark (Citizens' Gas Co.).	do	600		50		

[1] Record, etc., New Jersey Geol. Surv., Report for 1898, pp. 98–100.
[2] Record, etc., New Jersey Geol. Surv., Report for 1884, p. 127; 1885, p. 133.
[3] Record, etc., New Jersey Geol. Surv., Report for 1885, p. 131; 1894, pp. 190–193.
[4] Record, etc., New Jersey Geol. Surv., Report for 1894, pp. 407–409.
[5] Record, etc., New Jersey Geol. Surv., Report for 1896, pp. 126–127.
[6] Record, etc., New Jersey Geol. Surv., Report for 1896, pp. 166–168.
[7] Record, etc., New Jersey Geol. Surv., Report for 1897, pp. 247–248.
[8] Record, etc., New Jersey Geol. Surv., Report for 1894, pp. 200–201.
[9] Record, New Jersey Geol. Survey, Reports for 1879, p. 132; 1882, p. 139; 1885, p. 111.
[10] Ibid., Report for 1895, pp. 147–148.
[11] Ibid., Report for 1880, p. 165.
[12] Ibid., Reports for 1879, pp. 130–132; 1882, pp. 138–140; 1885, p. 118.
[13] Ibid., Reports for 1880, p. 172; 1882, p. 139; 1885, p. 111.
[14] Ibid., Report for 1898, p. 140.
[15] Ibid., Report for 1888, p. 77.
[16] Ibid., Report for 1897, pp. 247–248.
[17] Record, etc., New Jersey Geol. Surv., Report for 1894, p. 75.
[18] Record, etc., New Jersey Geol. Surv., Report for 1885, p. 131; 1884, p. 125; 1895, pp. 148–149.
[19] Record, etc., New Jersey Geol. Surv., Report for 1898, pp. 96–98; 1899, pp. 73–74.
[20] Record, etc., New Jersey Geol. Surv., Report for 1895, pp. 83–85.
[21] Record, etc., New Jersey Geol. Surv., Report for 1895, p. 77.
[22] Record, etc., New Jersey Geol. Surv., Report for 1893, pp. 413–414.

NEW JERSEY—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Newark	Essex	615	8	556		
Newark (Balentine's).[1]	do	450	8	200		
Newark (smelter)[2]	do	500	8	500		
New Brunswick[3]	Middlesex	455	1½			
Do.[4]	do	480		Few.		Very hard water.
Do	do	976	8	7		Water at 300-350 feet.
North Spring Lake	Monmouth	705	6	100	Flows.	
Ocean Beach[5]	do	485	3	25	+34	
Do.[6]	do	480	3	50	Flows.	
Ocean Grove[6]	do	420	6	40	Flows.	Temp. 60°.
Do.[7]	do	1,134			Flows.	
Ocean City[8]	Cape May	800		140	Flows.	
Do.[9]	do	821	8	Many.	Flows.	
Do.[10]	do	760		Many.	Flows.	
Do	do	830	8-6	Many.	Flows.	
Passaic	Passaic	402	8	240	−28	
Do	do	558	8	112	−28	Water at 400 feet.
Do	do	1,000		Few.		
Paterson[11]	do	2,100	8-4	100		Water at 900 feet only.
Do	do	900		100		
Point Pleasant[12]	Ocean	806		45	Flows.	
Poplar		520			−30	
Reedy Island[13]		570		20	Flows.	
Sayreville[14]	Middlesex	976	8	7		Some water at 300 feet.
Seabright[15]	Monmouth	715	6-4½		−5	Water 260-300, 350-390, 685-715 feet.
Seagirt[16]		755	3	50	Flows.	Temp. 65°; water also at 570 and 694 feet.
Seaside Park[17]	Ocean	515		16	Flows.	Temp. 58°.
Sea Isle City[18]	Cape May	464			Flows.	
Do[19]	do	854	6	160	+14	
Secaucus[20]	Hudson	600	6	8	No flow.	Water from 200 to 250 feet.
Seven Islands[21]		408	6-3	70	Flows.	
Do		535		60	Flows	
Sewell	Gloucester	420	3			Water also at 72, 381, and 395 feet.
Smiths Landing[22]	Atlantic	715	6	100	−17	
South Beach Haven[19]	Ocean	425	8-6	10	+14	
Spring Lake	Monmouth	465-730			Flows.	
Telegraph Hill[23]		575				
Toms River[24]	Ocean	745				
Union	Union	500			Flow.	Ten wells.
Ventnor[25]	Atlantic	813	6		Flows.	
West Asbury Park[26]	Monmouth	508-558		150 each		Four wells.
Waverly	Union	450		Few.		
Wildwood	Cape May	655		300	Flows.	Temp. 63°.
Do[27]	do	1,244		10	Flows.	Temp. 67°; water at 625, 750, 843, and 1,185 feet.
Woodstown	Salem	776				

[1] Record, etc., New Jersey Geol. Surv., Reports for 1879, p. 126; 1882, p. 142; 1885, p. 115.
[2] Record, etc., New Jersey Geol. Surv., Report for 1879, p. 126; 1882, p. 142; 1885, p. 114.
[3] Record, etc., New Jersey Geol. Surv., Report for 1879, p. 133; 1882, p. 147; 1885, p. 113.
[4] Record, etc., New Jersey Geol. Surv., Report for 1887, p. 27.
[5] American Journal of Science, 3d series, vol. 30, p. 162.
[6] Record, etc., New Jersey Geol. Surv., Reports for 1884, p. 124; 1885, pp. 129-131.
[7] Record, etc., New Jersey Geol. Surv., Report for 1894, pp. 74-75.
[8] Record, etc., New Jersey Geol Surv., Report for 1893, pp. 398-399.
[9] Record, etc., New Jersey Geol. Surv., Report for 1896, pp. 171-173.
[10] Record, etc., New Jersey Geol. Surv., Report for 1892, pp. 279-281.
[11] Record, etc., New Jersey Geol. Surv., Report for 1879, p. 128; 1882, p. 143; 1885, pp. 115, 117.
[12] Record, etc., New Jersey Geol. Surv., Report for 1895, pp. 76-77.
[13] Record, etc., New Jersey, Geol. Surv., Report for 1895, pp. 141-142; 1897, pp. 248-249.
[14] Ibid., Report for 1887, p. 27; 1888, p. 77.
[15] Ibid., Report for 1899, pp. 76-77.
[16] Ibid., Report for 1895, pp. 75-76.
[17] Ibid., Report for 1898, pp. 101-102.
[18] Ibid., Report for 1890, p. 268.
[19] Ibid., Report for 1896, pp. 175-177; 1886, p. 211; 1899, p. 109.
[20] Ibid., Report for 1879, p. 129; 1880, p. 172.
[21] Ibid., Report for 1885, p. 135; 1891, pp. 230-231.
[22] Ibid., Report for 1899, pp. 104-106.
[23] Ibid., Report for 1896, p. 153.
[24] Ibid., Report for 1893, pp. 399-400; 1894, pp. 159-180; 1898, pp. 102-103.
[25] Ibid., Report for 1898, pp. 76-78.
[26] Ibid., Report for 1899, pp. 74-76.
[27] Ibid., Report for 1897, pp. 247-248.

PUBLICATIONS RELATING TO DEEP BORINGS IN NEW JERSEY.

New Jersey Geological Survey, Reports of the State Geologist for 1868, 1879, 1882 to 1885, 1887 to 1889, 1890, 1892 to 1899.

United States Geological Survey, Bulletin, No. 138, Artesian Well Prospects in the Atlantic Coastal Plain Region, by N. H. Darton, pp. 39–115, plates, Washington, 1896.

NEW MEXICO.

Location.	County.	Depth.	Diameter	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Deming	Grant	980	6	Many.	— 18	Never used.
Eddy [1]	Eddy	+600			No flow.	
Gallup	McKinley	600	10	Several.	−225	No water below 135 feet.
Guam	do	600	10			
Las Vegas	San Miguel	1,860	6	Several.	— 30	Strongly mineral water; abandoned.
Manuelito	McKinley	610	10	Few.		Unsatisfactory water.
Raton	Colfax	1,878	6	Few.	—300	Two wells; abandoned.
Do	do	1,872	6		—300	
Santa Fe	Sante Fe	1,115				

PUBLICATIONS RELATING TO DEEP BORINGS IN NEW MEXICO.

Report on New Mexico, by L. G. Carpenter, Fifty-first Congress, first session, Senate Ex. Doc., No. 222, pp. 233–241, Washington, 1890.

Report of P. H. Van Diest, on the Geological Conditions of Artesian Basins in Eastern Colorado and New Mexico, Fifty-first Congress, first session, Senate Ex. Doc., No. 222, pp. 233–241, Washington, 1890.

On the Occurrence of Artesian and Other Underground Waters in Texas, eastern New Mexico, and Indian Territory west of the ninety-seventh meridian, by Robert T. Hill. A Report on Irrigation, etc., by R. J. Hinton, Fifty-second Congress, first session, Senate Ex. Doc., No. 41, part 3, pp. 41–166, Washington, 1893.

NEW YORK.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Albany	Albany					City wells.
Alexander	Genesee					Salt well.
——[2]	Allegany	839–1,800				Important field of oil wells, embracing over 6,500 borings. Some 3,000 feet deep.
Attica [3]	Wyoming	1,960				Salt well.
Auburn [4]	Cayuga	3,570				Gas well.
Do	do	3,400?				
Aurora [5]	do	1,068				Salty water.
Baldwinsville	Onondaga	2,358	6¼			Gas well.
Baldwinsville (1 mile south).[6]	do	2,250				Do.
Baldwinsville (1 mile north).[7]	do	2,795				Do.
Ballston	Saratoga	560			+60	Mineral water.

[1] Record, Report on Irrigation. Fifty-second Congress, first session, Senate Ex. Doc. No. 41, part 2, p. 16, Washington, 1893.
[2] Records, Am. Inst. Mining Engineers, Trans., vol. 16, pp. 930–934.
[3] Record, Report of Supt. Onondaga Salt Springs for 1888, pl. 2.
[4] Record, American Geologist, vol. 25, pp. 156–160.
[5] Record, Report of Supt. Onondaga Salt Springs for 1888, pl. 2.
[6] Record, American Geologist, vol. 25, pp. 150–152.
[7] Ibid., p. 154.

NEW YORK—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Barker	Niagara	2,175				Salt, oil, and gas.
Barren Island [1]	Queens	720	6	50	Flows.	Excellent water.
Do [2]	do	740			Flows.	
Batavia	Genesee					
Bath (1 mile south)	Steuben	2,050				Gas well.
Binghamton [3]	Broome	3,117				
Binghamton (north of).	do	2,000				
Bristol [4]	Ontaria	+750				Salt well.
Brockport	Monroe	2,000				For gas; unsuccessful.
Brooklyn borough (Calvary Cemetery.) [5]	Kings	582		70		Soft water.
Brooklyn borough (foot of Thirty-ninth and Fortieth streets).	do	1,503	8-6			Salt water.
Buffalo	Erie	490	6			Gas well.
Do. [6]	do	1,365	5¾			Do.
		516-525				Several gas wells.
Do	do	560				Gas well.
Burden	Columbia	900				
Cairo (3½ miles southwest). [7]	Greene	2,200	5⅝		−310	For oil or gas; abandoned.
Caledonia	Livingston	1,100	8-6¼		− 25	Salty, sulphurous water.
Do. [8]	do	760				Salt well.
Campbell [9]	Steuben	2,250				For oil or gas.
Canandaigua	Ontario					Several oil wells.
Canastota	Madison	648				Bitter brines.
Canisteo	Steuben	2,000				Several unsuccessful borings for gas.
Cardiff [8]	Onondaga	844				
Castile [8]	Wyoming	2,525				Salt well.
Cedarville	Onondaga	1,157				Do.
Charlotte Center [10]	Chautauqua	2,332				For oil; unsuccessful.
Do. [11]	do	2,262				Do.
Chittenango [12]	Madison	3,026				Gas well.
Clifton Springs [8]	Ontario	710				Salt well.
Clyde	Wayne	450	6		−12	
Do. [13]	do	1,792				
Clymer (4 miles east) [14]	Chautauqua	1,975				Gas well.
Cohocton (near)	Steuben					For oil.
Carfu (2 miles west)	Genesee	1,208 1,248	8-6¼		−15 and −135	Several gas wells.
Curlerville [8]	Livingston	1,145				Salt well.
Dansville	do	1,800				
Dundee	Yates	2,000				Rock salt at 1,800 feet.
Do	do	1,200				
Eagleville	Madison	1,889				
East Aurora [8]	Erie	1,465 1,503				Salt wells.
East Buffalo	do	1,000-3,000				For gas; unsuccessful.
Eden Valley [8]	do	1,750				Salt well.
Fredonia [15]	Chatauqua	1,207				Much salty water several gas wells in vicinity.
Fulton [16]	Oswego	1,656-2,050				Several gas wells.
Gardenville [17]	Erie	800				Salt well.
Gasport	Niagara	2,007				Gas at 1,086 feet.
Geneva	Ontario	550			Flows.	

[1] Record, N. J. Geol. Surv., Report 1896, pp. 155-156.
[2] Ibid., pp. 156-157.
[3] Record, Geol. Soc., of Am., Bull., vol. 4, pp. 93-94.
[4] Record, Rept. Supt. Onondaga Salt Springs for 1888, pl. 2.
[5] Record, U. S. Geol. Surv., Bull. 138, p. 34.
[6] Record, Am. Inst. Mining Engineers, Trans., vol. 16, pp. 924-925.
[7] Record, Am. Inst., Mining Engineers, Trans., vol. 16, p. 956.
[8] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2; Report for 1885, p. 15.
[9] Record, Geol. Soc. Am., Bull., vol. 4, pp. 97-100.
[10] Record, Pa. 2d Geol. Surv., Rept., vol. I[5], p. 325.
[11] Ibid., pp. 325-326.
[12] Record, Geol. Soc. Am., Bull. vol. 4, p. 101.
[13] Record, Am. Inst. Mining Engineers, Trans., vol. 16, p. 942.
[14] Record, Pa. 2d Geol. Surv., Rept., Vol. I[5], p. 228.
[15] Analysis, Am. Inst. Mining Engineers, Trans., vol. 16, pp. 918-923.
[16] Record, Geol. Soc. of Am., Bull., vol. 4, pp. 105-106.
[17] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2.

NEW YORK—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Getzville	Niagara	1,400				Several good gas wells.
Glen Springs	Schuyler	1,500				For oil; unsuccessful.
Gowanda [1]	Cattaraugus	1,700				Salt well.
Greenpoint [2]	Onondaga	1,600				
Greig	Lewis	700				Bored for oil.
Greigsville [3]	Livingston	1,138–1,145				Salt wells.
Hollis Station [4]	Queens	406				
Honeoye	Ontario	646				Gas at 610 feet; several gas wells in vicinity.
Honeoye Falls [5]	Monroe	1,500				Gas well.
Howard (one-half mile west).	Steuben	2,000				For oil or gas; unsuccessful.
Hudson	Columbia	602	6	1	−60	
Hornellsville	Steuben	1,500	6½			Gas at 650, 940, and 1,200 feet.
Do	do	1,522	6½			Gas well.
Ilion [6]	Herkimer	1,135				Gas in small quantities at 800, 950, and 1,000 feet.
Ithaca	Tompkins	2,250	10–6½			Two dry salt wells.
		2,250	8–5½			
Ithaca (one-fourth mile south).[7]	do	3,185	8–5½			Gas well.
Jamestown [8]	Chatauqua	1,807				Unsuccessful boring for oil.
Jamesville [9]	Onondaga	1,040				Salt well.
Knowersville [10]	Albany	3,012				Gas at 497 feet only.
Knowersville (4½ miles north).[11]	do	2,200				For gas; unsuccessful.
Lakeville [12]	Livingston	1,053				Salt well.
Leicester	do	1,165				Do.
Leroy [13]	Genesee	878–1,003				Salt wells.
Limestone [14]	Cattaraugus	1,500	4½			For gas or oil.
Liverpool	Onondaga	600–1,969				Salt wells.
Livonia [15]	Livingston	1,432	Shaft.			Salt mine.
Do	do	1,100				Salt well.
Lockport	Niagara					Do.
Ludlowville	Tompkins	1,821	8			Salt wells.
Middletown	Orange	2,010	10–8	80	Flows.	
Do	do	600	6		−60	Two wells.
Mohawk	Herkimer	420	6		−30	Sulphurous water, unfit for use.
Montfredys Mills	Onondaga	1,140				Salt well.
Morrisville [16]	Madison	1,889				Gas well.
Mount Morris [17]	Livingston	1,130–1,422				Several salt wells.
Naples	Ontario	1,650				Salt well.
Neversink (near)	Sullivan	1,400				Gas boring; abandoned.
New Dorp	Richmond	600				No water.
New Rochelle	Westchester	1,155	10		−10	
New York City, 10th and Washington sts.	New York	500	6	600	No flow.	
New York City, 11th and Greenwich sts.	do	1,047	8	10	No flow.	
New York City, 28th st., near Broadway.	do	500	8	100	No flow.	
New York City, 47th st. and 4th ave.	do	600	8	100	No flow.	

[1] Ibid.
[2] Ibid. for 1884, pp. 12–15; 1888, pl. 2.
[3] Ibid., 1888, pl. 2.
[4] Record, U. S. Geol. Surv., Bull. 138, pp. 30–31.
[5] Record, Pa. 2d Geol. Surv., Report, Vol. I^5, p. 326.
[6] Record, American Geologist, vol. 25, pp. 132–135.
[7] Record and analysis, Am. Inst. Mining Engineers, Trans., vol. 16, p. 941; Report Supt. Onondaga Salt Springs for 1888, pl. 2.
[8] Record, Pa. 2d Geol. Surv., Report, Vol. I^4, p. 126.
[9] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2.
[10] Record and analysis, Am. Inst. Mining Engineers, Trans., vol. 16, pp. 951–952.
[11] Am. Inst. Mining Engineers, Trans., vol. 16, pp. 953–954.
[12] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2.
[13] Ibid., Report for 1884, pp. 19–20.
[14] Record, Pa. 2d Geol. Surv., Report, Vol. II., p. 272.
[15] American Geologist, vol. 15, p. 379; N. Y. State Geologist Report, 1893, vol. 1, p. 13.
[16] Record, Geol. Soc. of Am., Bull., vol. 4, pp. 96–97; Report Supt. Onondaga Salt Springs for 1888, pl. 2.
[17] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2.

NEW YORK—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
New York City, 59th st. and 11th ave.	New York	700	8	100	No flow.	
New York City, 72d st. and 8th ave.	do	1,200	8	8	No flow.	
New York City, 59th st. and 5th ave.	do	500		80	No flow.	
New York City, 92d st. and 3d ave.	do	685	9	300	No flow.	
New York City, 145th st. and 8th ave.	do	605	10-8		No flow.	
New York City, Washington Building.	do	1,000			No flow.	
New York City, Manhattan Insurance Building.	do	1,056	8	75	No flow.	
New York City, Liberty and Nassau sts.	do	720		80	No flow.	
New York City, N. Y. Life Ins. Building.	do	500			No flow.	
New York City, Fulton Market.	do	626			No flow.	
New York City, Broadway and Bleecker st.	do	448	7	80	No flow.	
New York City, Lafayette and Barnard sts.	do	700	8	80	No flow.	
New York City, Boulevard and 72d st.	do	700		25		Hard water.
New York City, 146th st. and 8th ave.	New York	1,035	8	500	No flow.	
New York City, 99th st.	do	609	8		No flow.	Abandoned.
Do	do	1,505	8	11	No flow.	Do.
New York City, 67th st. near 3d ave.	do	1,504	8		−32	Do.
New York City, 67th st. near 2d ave.	do	1,502	8	50	−38	Do.
New York City, Morris and Greenwich sts.	do	625	8	40	No flow.	Do.
Do	do	700	8		No flow.	Do.
New York Mills [1]	Oneida	2,000				Gas at 500 feet.
Niskayuna	Schenectady	400	6	75	−20	
Norwich	Chenango	900				Small amount of gas
Do.[2]	do	2,334				Do.
Nunda [3]	Livingston					
Olean [4]	Cattaraugus	1,230				Gas well.
Pearl Creek	Wyoming	1,182-1,194				Salt wells.
Pearl Creek (1 mile south).	do	1,241				Salt well.
Perry [5]	do	2,108				Heavy bed of salt.
Penn Yan [5]	Yates					Small supply of gas for several weeks.
Phoenix	Oswego	2,600				Gas well.
Piffard [6]	Livingston	961-1,141				Several salt wells.
Port Colborne [7]	Erie	770-1,500				Several small gas wells.
Port Jervis	Orange	1,400				Unsuccessful.
Richland	Oswego					Numerous gas wells
Rock City (near) [8]	Dutchess	1,471-1,546				Oil wells.
Rock Glen [3]	Wyoming	2,111				Salt well.
Rome [9]	Oneida	1,632				Gas wells.
Do. [10]	do	832				Gas well.
Saltvale [3]	Wyoming	1,436				Salt well.
Sandy Creek	Oswego	1,000-1,260				Numerous oil wells.
Do. [11]	do	1,145				Gas at 675, 765, and 79 feet.

[1] Am. Inst. Mining Engineers, Trans., vol. 16, pp. 958-959.
[2] Record, Geol. Soc. of Am., Bull., vol. 4, p. 95.
[3] Record, Report Supt. Onondaga Salt Springs for 1888, pl. 2.
[4] Am. Inst. Mining Engineers, Trans., vol. 16, pp. 939-940.
[5] Ibid.
[6] Record, Report Supt. Onondaga Salt Spring for 1884, pp. 20-21.
[7] Record, Am. Inst. Mining Engineers, Trans., vol. 17, p. 401.
[8] Record, Pa. 2d Geol. Surv. Report, vol. I[4], p. 100.
[9] Record, American Geologist, vol. 25, pp. 137-143.
[10] Ibid., p. 145.
[11] Record, Geol. Soc. Am., Bull., vol. 4, p. 107.

NEW YORK—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Saratoga Springs	Saratoga	400	6	3¼		
Do	do	1,006	2⅝	2	+75	
Do	do	600	6	¼	Flows.	
Do	do	440	6	½	+40	
Do	do	520	6	½	+40	
Do	do	425	6	¾	−16	
Saratoga Springs	Saratoga	478?			+40	Mineral water.
Do	do	422			−16	
Shodack Landing	Rensselaer	1,000?				Salt well.
Seneca Falls	Seneca	3,560				Gas well.
Do	do	400-500			Flow.	Several salt wells in vicinity.
Do.[1]	do	1,500				Gas well.
Silver Springs[2]	Wyoming	2,254				Salt well.
Springfield[3]	Otsego	419		2	No flow.	
Syracuse (near)[4]	Onondaga	1,115-1,969				
Tivoli	Dutchess	400				
Tully[5]	Onondaga	974-1,472				Numerous salt wells.
Uniontown	Madison					Gas well.
Utica[6]	Oneida	860				Gas well.
Do.[7]	do	1,720				
Vernon[8]	do	1,968				Gas well.
Warsaw[9]	Wyoming	1,609-2,039				Numerous salt wells.
Watertown[10]	Jefferson	530				Small flow of gas at 253 feet.
Watkins	Schuyler	2,100				Several salt wells.
Wellsville (4¾ miles southwest).[11]	Allegheny	1,177				Oil well.
West Bloomfield[12]	Ontario	500	5			Gas well.
Whitneys Point (near).	Broome	1,120				Salt well.
Willets Point	Queens	400				
Williamsville	Erie	Av. 875	5⅝		No flow.	Three wells; two unsuccessful.
Wolcott[13]	Wayne	2,383				Gas well.
Woodhaven[14]	Queens	577				
Woodhull	Steuben	3,000			+50	Unsuccessful oil well; flow of water at 300 feet.
Wyoming[15]	Wyoming	1,321-1,530				Salt wells.
York[16]	Livingston	828				Salt well.

[1] Record, Am. Inst. Mining Engineers, Trans., vol. 16, p. 949.
[2] Record, Rept. Supt. Onondaga Salt Springs for 1888, pl. 2.
[3] Record, U. S. Geol. Surv., Bull. 138, p. 29.
[4] Record, Geol. Soc. Am., Bull., vol. 4, pp. 102-105; Am. Inst. Mining Engineers, Trans., vol. 16, p. 944; Rept. Supt. Onondaga Salt Springs for 1888, pl. 2; for 1884, pp. 15-18.
[5] Record, Geol. Soc. Am. Bull., vol. 4, p. 105; Rept. Supt. Onondaga Salt Springs for 1888, pl. 2.
[6] American Geologist, vol. 25, p. 137.
[7] Record, Geol. Soc. Am., Bull., vol. 4, p. 100.
[8] Record, Am. Geol. vol. 25, pp. 145-149.
[9] Record, Rept. Supt. Onondaga Salt Springs for 1888, pl. 2.
[10] Record, Geol. Soc. Am., Bull., vol. 4, p. 107.
[11] Record, Pa. 2d Geol. Surv., Ann. Rept., 1886, part 2, pp. 774-775.
[12] Am. Inst. of Mining Engineers, Trans., vol. 13, p. 542.
[13] Ibid., vol. 16, p. 943.
[14] Record, U. S. Geol. Surv., Bull. 138, pp. 31-32.
[15] Record, Rept. Supt. Onondaga Salt Springs for 1888, pl. 2.
[16] Ibid.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN NEW YORK.

Annual Report of Superintendent of Onondaga Salt Springs for 1888, 26 pages, plates, Albany, 1889.

The Thickness of the Devonian and Silurian Rocks of Central New York, by C. S. Prosser, American Geological Society, Bulletin, vol. 4, pp. 91-118, Rochester, 1893.

United States Geological Survey, Bulletin No. 138, 232 pages, Washington, 1896.

Gas Well Sections in the Upper Mohawk Valley and Central New York, by C. S. Prosser, American Geologist, vol. 25, pp. 131-162, March, 1900.

Petroleum and Natural Gas in New York State, by C. A. Ashburner, American Institute of Mining Engineers, Transactions, vol. 16, pp. 906-953.

NORTH CAROLINA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Charlotte	Mecklenberg	900	2			Dry.
Davidson	do	500				Dry below 80 feet.
Durham	Durham	1,037		18	No flow	
Gold Hill	Rowan	1,000			−20	Shaft sunk for gold.
Hammocks	New Hanover	400		8		Water at 100 feet.
Monroe	Union	720	6-5	28	To surface.	
Do	do	1,050	8-6	28	Near surface.	
North Wilkesboro	Wilkes	600	8	85		Uncompleted.
Sanford	Moore	515	6⅝	45	−3	
Selma	Johnston					Two deep wells.
Walnut Cove	Stokes	1,050	2½			Unsuccessful; bored for coal.
Do (1 mile south)	do	500				Good flow of mineral water.
Wilmington	New Hanover	495			Flows.	Saline water.
Do	do	1,144	12-6	200		Flows of brackish water at 379, 496, 574, 608, 734, and 989 feet; 200-gallon flow at 518 feet; granite, 1,109 feet to bottom.

PUBLICATIONS RELATING TO DEEP BORINGS IN NORTH CAROLINA.

Artesian Well Prospects in the Atlantic Coastal Plain Region, by N. H. Darton, U. S. Geological Survey. Bulletin No. 138, 232 pages, plates, Washington, 1896.

NORTH DAKOTA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bismarck [1]	Burleigh	1,315	8-4			No flow.
Devils Lake [2]	Ramsey	1,520	8-3	82	+46	Flow at 1,470 feet.
Dickinson	Stark	1,325				No flow.
Edgeley	Lamoure	1,354	6	500	+138	Water at 1,300 and 1,350 feet.
Ellendale [1]	Dickey	860			+138	
Do [1]	do	1,087	4⅝-3⅜	700	+260	Water at 1,042 feet.
Grafton [2]	Walsh	912	8	700		
Hamilton City [3]	Pembina	1,565	6	16½	+60	
Jamestown (asylum). [3]	Stutsman	1,524	8-3½	4	+161	
Jamestown [1]	do	1,476	6¼-3½	460	+223	Water at 1,385 and 1,458 feet.
Mandan [1]	Morton	2,000	10-4	3		Water at 327 feet only.
Medora [1]	Billings	941	4	33	+34½	
Oakes [1]	Dickey	977				Water at 790, 845, 870, and 937 feet.
Portland	Traill	560		175	Flows.	
Rutland [3]	Sargent	600	2			
Sims [1]	Morton	1,311				No flow.
Staples		514		25	+115	
Towers City [1]	Cass	716	6-4½	20-25	+122	
Wimbleton [1]	Barnes	1,557		200	+184	

[1] U. S. Geol. Surv., 17th Ann. Rept., 1895-96, part 2, pp. 59-63.
[2] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 107 108, Washington, 1890.
[3] 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 322, Washington, 1890.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN NORTH DAKOTA.

Report of F. S. Underhill for North Dakota, Fifty-first Congress, first session, Senate Ex. Doc. No. 222, pp. 105–109, Washington, 1890.

Report on Irrigation, Fifty-second Congress, first session, Senate Ex. Doc. No. 41, part 2, pp. 66–72, 87–94, Washington, 1893.

Preliminary report on Artesian Waters of a portion of the Dakotas, by N. H. Darton, United States Geological Survey, Seventeenth Annual Report, 1895–96, part 2, pp. 609–694, Washington, 1896.

OHIO.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*		
Ada [1]	Hardin	1,384–1,820				Several wells for gas; some successful, others yield only flows of salt water.
Amanda Township	Allen	1,200	10–5½		75	Salt water at 20 feet.
Akron [2]	Summit	2,250				
Do. [3]	do	2,450				Some gas at 172 feet.
Arcadia [4]	Hancock	1,365				Gas at 1,180 feet.
Arcanum [5]	Darke	+1,150				Gas prospects; small product.
Arlington [6]	Hancock	1,304				Some oil and gas at 1,304 feet. Abandoned.
Ashtabula [7]	Ashtabula	500				Gas from 250 to 500 feet. Strong brine at 400 and 500 feet.
Athens	Athens	±1,200				Oil and gas wells.
Bairdstown	Wood	1,058				Gas wells.
Bairdstown (1½ miles north). [8]	do	1,154				Gas well.
Bairdstown (near) [9]	do	1,154				For gas. Abandoned.
Barnesville [10]	Belmont	2,700				Gas wells.
Beaverdam	Allen	1,309				For oil; salt water found. Abandoned.
Beaverdam (5 miles east). [11]	Hancock	1,288–1,290				Gas wells.
Belden (near)	Lorain					Many oil wells.
Bellaire [12]	Belmont	1,550, 2,700				Small gas wells.
Belle Center [13]	Logan	+1,310				Very small flow of gas.
Bellefontaine [14]	do	1,590				Do.
Bellevue [15]	Huron	1,700				Forgas, unsuccessful.
Belpre [16]	Washington	+1,740				
Berea (2½ miles northeast). [17]	Cuyahoga	960–1,240				Several gas wells.
Birmingham [18]	Erie	2,250				Salt water only.
Bloomingville [19]	Hocking	628				Small flow of oil.
Do	do					Two borings.
Bloomdale [20]	Wood	1,115				Large flow of gas.
Bloomville [21]	Seneca	2,150				For oil unsuccessful.
Bluffton [22]	Allen	1,328				Unsuccessful.
Bowling Green [23]	Wood	±1,300				Gas well.
Do [24]	do	1,152				Large volume of gas.
Bradner [25]	do	1,244				Small flow of oil.
Brooklyn Village [26]	Cuyahoga	1,033				Several gas wells in vicinity.
Brownhelm [27]	Lorain	740				A little gas and oil.

[1] Ohio Geol. Surv., Report, 1888, vol. 6, p. 219; report for 1890, pp. 184–186.
[2] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 319.
[3] Ibid., pp. 357–358.
[4] Ibid., p. 217.
[5] Ibid., pp. 272–273.
[6] Ibid., p. 218.
[7] Ibid., pp. 424–425.
[8] Ibid., pp. 229–232.
[9] Ibid., pp. 232–233.
[10] Ibid., Report, 1890, p. 254.
[11] Ibid., Report, 1888, vol. 6, pp. 215–216.
[12] Record, ibid, p. 406.
[13] Record, ibid, p. 267.
[14] Record, ibid, pp. 266–267.
[15] Ibid., pp. 214–215.
[16] Ibid., p. 401.
[17] Records, ibid, pp. 433–436.
[18] Ibid., pp. 346–347.
[19] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 393–394.
[20] Ibid., pp. 233–234.
[21] Ibid., p. 201.
[22] Ibid., p. 216.
[23] Ibid., pp. 156–159, pl., p. 112.
[24] Ibid., p. 160.
[25] Ibid., p. 207.
[26] Ibid., pp. 430–431.
[27] Ibid., pp. 437–438.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet	*Inches.*	*Gallons.*	*Feet.*	
Brownhelm [1]	Lorain	635				Some oil.
Brown Township	Vinton	1,000	10-5½			Oil, gas, and salt water.
Bryan [2]	Williams	1,974-2,037				Gas and oil wells; yield small; salt water at 2,037 feet.
Buckeye (east of) [3]	Knox					Gas wells.
Bucyrus [4]	Crawford	840-2,264				For gas or oil; salt water flow at 780 feet.
Cadiz oil field [5]	Harrison					Fair flow of oil.
Cambridge [6]	Guernsey	1,090-2,000				Gas and oil wells; yield small.
Camden [7]	Preble	900				Gas well.
Canal Dover [8]	Tuscarawas	2,760				Little gas and salt water.
Cannonsburg [9]	Hancock	1,300				Several oil wells.
Canton [10]	Starke	2,220				For oil, but only salt water found.
Do	do	+3,135				
Cardington [11]	Morrow	±2,300				Gas; small flow.
Carey and vicinity [12]	Wyandot	1,326-1,500	5½			Several gas wells; some yield large supply.
Carroll [13]	Fairfield	2,300				Unsuccessful.
Celina [14]	Mercer	1,147-1,168				Gas wells.
Chicago Junction [15]	Huron	1,250				
Circleville	Pickaway					
Cincinnati (vicinity)	Hamilton					Numerous oil or gas wells; unsuccessful.
Cleveland [16]	Cuyahoga	400-1,500				Several gas wells.
Cleveland (gas company). [17]	do	2,200				No product.
Cleveland (Euclid and Case avenues). [18]	do	1,125-1,735				Small flow of gas.
Cleveland (Rolling Mill). [19]	do	3,000				
Cleveland (Central avenue).	do	535		Many.	+100	Large supply of water.
Cleveland (Gordon Park). [20]	do	520				Abandoned.
Cleveland (2 miles east). [21]	do	508				For oil and coal, unsuccessful.
Clyde [22]	Sandusky	1,850				Unsuccessful.
Coldwater (3½ miles east).	Mercer	1,100	8-5½		15?	
Columbus Grove [23]	Putnam	1,278				Gas at 740 feet; some oil at bottom.
Columbus [24]	Franklin	2,020				No gas or oil.
Columbus (State House). [25]	do	2,775	6-4		+5	Saline water below 675 feet; temp. 91°.
Conneaut [26]	Ashtabula	850				Small gas supply.
Do	do	+1,942				Much strong brine.
Coshocton [27]	Coshocton	2,108				
Do. [28]	do	1,280				Unsuccessful.
Do. [29]	do	3,100				Do.
Coventry Township	Summit					
Covington [30]	Miami					Small supply of gas.
Crestline [31]	Richland	2,864				
Cridersville	Auglaize	1,227	8-5½		+40	Oil and salt water.

[1] Record, Pa., 2d Geol. Surv., Report II, p. 282.
[2] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 247-249, 786.
[3] Ibid., pp. 346-343.
[4] Ibid., pp. 363-364.
[5] Ibid., Report, 1890, pp. 250-252.
[6] Ibid., Report, 1888, vol. 6, pp. 320, 377-378.
[7] Ibid., p. 285.
[8] Ibid., pp. 320, 369-370.
[9] Ibid., p. 217.
[10] Ibid., pp. 359-360.
[11] Ibid., pp. 283-284.
[12] Ibid., pp. 203-207.
[13] Ibid., p. 388.
[14] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 259-260.
[15] Ibid., pp. 350-351.
[16] Ibid., pp. 429-430.
[17] Ibid., p. 430.
[18] Geol. Soc. Am., Bull., vol. 8, p. 10.
[19] Record, Mich. Geol. Surv., Report, 1881-1893, vol. 5, part 2, p. 73; Ohio Geol. Surv., Report, vol. 1, pp. 352-355; Ohio Geol. Surv., Report, 1888, vol. 6, pp. 351-355.
[20] Geol. Soc. Am., Bull., vol. 8, p. 10.
[21] Economic Geology of Ill., vol. 3, pp. 195-6.
[22] Ohio Geol. Surv., Report, 1888, vol. 6, p. 214.
[23] Ibid., p. 242.
[24] Record, ibid., pp. 281-283.
[25] Record, ibid., pp. 106-108; Am. Journal Science, 2d series, vol. 27, p. 276.
[26] Ohio Geol. Surv., Report, 1888, vol. 6, pp. 422-423.
[27] Record, ibid., p. 324.
[28] Ibid., p. 368.
[29] Ibid., p. 357; Report for 1890, pp. 245-246.
[30] Ibid., p. 274.
[31] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 303-304.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Dayton [1]	Montgomery	870				Some shale gas.
Do. [2]	do	2,440			200	
Defiance	Defiance	1,687				Salt water only.
De Graff [3]	Logan	1,356				Some oil and gas.
De Graff (1 mile west)	do	1,300	8-5⅛			
Delaware [4]	Delaware	2,130				Unsuccessful.
Delphos [5]	Allen	1,250				Do.
Delphos (Kill farm) [6]	do	1,218				Oil well.
Delta [7]	Fulton	2,150				Unsuccessful.
Deshler [8]	Henry	1,600				Only small flow of gas.
Dexter (near)	Noble					
Dresden [9]	Muskingum	2,525				
Do. [10]	do	+1,000				Unsuccessful.
Duchouquet	Auglaize					Two wells of moderate flow.
Dudley	Noble					
Dunkirk [11]	Hardin	1,865			—445	For gas; only salt water found.
Dunkirk [12]	do	1,370				Large flow of oil.
Eagle Mills	Vinton	600				Salt water.
Eaglesport [13]	Morgan	1,134				Salt water; abandoned.
Do	do	1,152	8-6			Oil rises to 40 feet.
East Liverpool [14]	Columbiana	425-450				
East Liverpool (on Dry Run). [15]	do	±3,000				Several gas wells.
East Liverpool (Knowles well).	do	2,954				Dry.
Eaton [16]	Preble	1,170-1,375				Several wells; unsuccessful.
Elnore [17]	Ottawa	+1,250				Two oil wells.
Elyria [18]	Lorain	987				Small gas supply and heavy flow of salt and sulphur water.
Felicity [19]	Clermont	400				Gas well.
Findlay [20]	Hancock	1,116-1,334				Many gas wells; some oil in several wells.
Do. [21]	do	1,648				Gas well; oil at 1,092 feet; salt water at 1,581 feet.
Findlay (1 mile northwest). [22]	do	1,334				Unsuccessful.
Flushing (1 mile northeast). [23]	Belmont	1,680				Salt water only.
Forest [24]	Hardin	1,470				Unsuccessful.
Forest (3 miles southwest).	do	480		Many.	Flows.	White sulphur water.
Fort Jennings	Putnam	1,425	8		—25	Salt water.
Fort Recovery [25]	Mercer	1,052				Gas for several months.
Fostoria [26]	Seneca	1,136-1,775				Several gas wells.
Fremont and vicinity. [27]	Sandusky	1,300-1,500				Do.
Do. [28]	do	568				Gas well.
Gallipolis [29]	Gallia	2,910				For oil; unsuccessful.
Geneva [30]	Ashtabula	850-1,375				Two wells; fair flow of gas; numerous other wells in the county.
Genoa [31]	Ottawa	1,308				Small flow of oil and gas.
Greenville [32]	Darke	1,200-1,700				Several borings for gas; unsuccessful.

[1] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 288.
[2] Ibid., p. 286.
[3] Ibid., p. 268.
[4] Ibid., p. 270.
[5] Ibid., p. 240.
[6] Ibid., Report 1890, p. 217.
[7] Ibid., Report 1888, vol. 6, pp. 244-245.
[8] Ibid., p. 253.
[9] Ibid., Report 1890, p. 246.
[10] Ibid., Report 1888, vol. 6, p. 376.
[11] Ibid., p. 223.
[12] Ibid., Report 1890, p. 186.
[13] Ibid., Report 1888, vol. 6, pp. 389-390.
[14] Ibid., pp. 331-334
[15] Ibid., pp. 322-323.
[16] Ibid., pp. 108, 284.
[17] Ibid., pp. 211-212.
[18] Ibid., pp. 347-348.
[19] Ibid., p. 301.
[20] Ibid., pp. 122-133, 146; Report for 1890, p. 125.
[21] Ibid., Report 1888, vol. 6, pp. 111-117.
[22] Ibid., pp. 131-132.
[23] Ibid., Report 1890, pp. 253-254.
[24] Ibid., Report 1888, vol. 6, p. 223.
[25] Ibid., pp. 263-264.
[26] Ibid., pp. 192-193, 146, 234.
[27] Ibid., pp. 183-189.
[28] Ibid., p. 188.
[29] Record, Pa. 2d Geol. Surv., Reports, vol. I[5], p. 335.
[30] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 425-426.
[31] Ibid., p. 213.
[32] Ibid., pp. 271-272.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Hamden	Vinton	780				Nothing but salt water.
Hamilton [1]	Butler	550-700				Gas wells; small flow.
Hammansburg [2]	Wood	1,194				Small flow of oil.
Harrisburg [3]	Franklin	405	6	Many.	Flows.	
Haskins	Wood					Oil well.
Henry Township [4]	do	1,125-1,150				Gas wells; some oil.
Do. [5]	do	1,212-1,295				Oil.
Hicksville [6]	Defiance	1,710				Salt water; some oil.
Hillsboro [7]	Highland	1,750				Good water at 1,750 feet.
Huntsville	Logan	1,460				Gas well.
Independence [8]	Cuyahoga	1,800				Several borings for oil; no product.
Ironton [9]	Lawrence	3,600				Unsuccessful.
Island Run [10]	Columbiana	600				
Jackson [11]	Jackson	1,600				Small flow of gas.
Jamestown	Greene	1,500				Salt water only.
Jerry City [12]	Wood	1,155				Two wells; one with fair supply of oil.
Joy [13]	Morgan	1,240				Only small flow of gas. Two wells; much salt water.
Kalida (1 mile north). [14]	Putnam	1,316				Bored for oil; salt water found.
Kenton [15]	Hardin	1,600				Unsuccessful.
Do	do					Do.
Kimbolton [16]	Guernsey	1,087				Do.
Do	do					Some gas.
Lacarne [17]	Ottawa	1,700				Much water.
Lafayette [18]	Madison					Unsuccessful.
Lancaster [19]	Fairfield	1,030				
Do. [20]	do	1,940 2,020	4½-5⅝			Several gas wells.
Lebanon [21]	Warren	700 and 1,300				Small flow of gas; much salt water.
Leipsic [22]	Putnam	1,456				Some oil and gas and great volume of salt water.
Lima [23]	Allen	1,200-1,400				Numerous oil wells here and in county; much salt water found.
Lindsey [24]	Sandusky	1,241-1,300	4			Three oil and gas wells; also flow; salt water in large quantities.
Lisbon [25]	Columbiana	1,582				
Little Sandusky	Wyandot	1,450	8-5⅝		−40	Salt water at 25 feet.
Logan [26]	Hocking	625-689				Several wells; some oil, water, and gas.
Do	do	1,002				Some oil.
London [27]	Madison	1,585				Several wells for oil or gas.
Lorain [28]	Lorain	+600			−50	Mineral water; some gas.
Lone Star	Vinton	1,100				Salt water; some oil.
McArthur	Vinton	900-1,000				Fresh and salt waters.
McComb [29]	Hancock	1,455				Gas well with salt water.

[1] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 292-293.
[2] Record, ibid., p. 237.
[3] Analysis, U. S. Geol. Surv., 19th Ann. Rept., 1897-1898, part 1, p. 6614.
[4] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 237-238.
[5] Record, Pa. 2d. Geol. Surv., Ann. Report for 1886, part 2, p. 786.
[6] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 250-251.
[7] Analysis, ibid., p. 297.
[8] Ibid., p. 431.
[9] Record, ibid., pp. 304-306, 319
[10] Record, Pa. 2d Geol. Surv., Ann. Report, 1886, part 2, pp. 784-785.
[11] Ohio Geol. Surv., Report, 1888, vol. 6, pp. 319-394.
[12] Ibid., p. 233.
[13] Ibid., p. 390.
[14] Record, ibid., p. 243.
[15] Ibid., p. 220.
[16] Ibid., pp. 380-381.
[17] Ibid., p. 213.
[18] Ibid., p. 219.
[19] Record, Ohio Geol. Surv. Report, 1886, vol. 6, p. 318.
[20] Ibid., pp. 382-388, 783.
[21] Ibid., pp. 295-296.
[22] Ibid., p. 242.
[23] Ibid., pp. 165-168.
[24] Ibid., pp. 213, 788-789.
[25] Ibid., p. 322.
[26] Ibid., pp. 318, 392-393.
[27] Ibid., pp. 280-281
[28] Ibid., pp. 438-439.
[29] Ibid., p. 219.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
McConnellsville	Morgan	+3,000				For oil or gas; unsuccessful.
Do	do	1,330	7½–5⅝			Gas and salt water.
McCuneville[1]	Perry	1,368				Several wells; bored for salt water; some found.
Macksburg[2]	Washington	400–1,700				Large oil field about here.
Do.[3]	do	2,100				Numerous successful wells; gas also found.
Do.[4]	do	2,500				Oil and gas well.
Madison Township	Vinton	1,017	10–5⅝			Very little oil and salt water.
Magnetic Springs[5]	Union	1,600				Salt well.
Malta[6]	Morgan					Large flow of gas from several wells for oil or salt.
Mansfield[7]	Richland	2,005–2,415				Two borings for gas; unsuccessful.
Do.[8]	do	3,594	5–4			Unsuccessful.
Marietta[9]	Washington	1,740–2,940				Oil well.
Marietta (4 miles below),[10]	do	1,440				Gas well.
Marietta (near)[11]	do	3,015				Much salt water at 1,790 feet.
Marion[12]	Marion	1,790				Abandoned.
Martins Ferry[13]	Belmont	2,300				
Marion Township[14]	Hancock					Gas well.
Marysville[15]	Union	1,743				For gas or oil; found only water at 300 feet.
Massillon[16]	Stark	655–1,820				Nothing but salt water.
Do.[17]	do	671				Some oil; also salt water.
Do.[17]	do	2,547				Gas at 655 feet, shut out by salt water.
Medina[17]	Medina	917				Small flow of gas.
Miamisburg[18]	Montgomery	800–1,200				Two gas wells.
Middleport	Meigs	950–1,250	3 and 4	Av. 25		Great number of salt-water wells in county.
Do	do	1,500				Small amount of oil from 120–1,500 feet.
Middletown[19]	Butler	1,060				Some gas and salt water.
Milan[20]	Erie	2,000				For oil or gas; only salt water found.
Millersburg[21]	Holmes	2,100				
Millersburg (four miles from).	do	900–1,000				Gas and oil well.
Millers Station[22]	Guernsey	430				Salt well.
Monroeville[23]	Huron					Small flow of gas only.
Mount Blanchard[24]	Hancock					Moderate flow of oil and gas.
Mount Orab	Brown	800–1,200	5⅝			Gas wells.
Mount Vernon[25]	Knox	1,370, 1,707, 2,600				Three wells; unsuccessful.
Do.[26]	do	3,200	4¼		—100	Gas well; water at 1,725 and 1,765 feet.
Do	do	2,135				Unsuccessful.

[1] Ibid., pp. 388–389.
[2] Ohio Geol. Surv., Report, 1888, vol. 6, pp. 450–464.
[3] Ibid., p. 453.
[4] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 333–334.
[5] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 269.
[6] Ibid., p. 389.
[7] Ibid., pp. 318, 365–366.
[8] Ibid., Report 1890, p. 245.
[9] Ibid., Report 1888, vol. 6, pp. 368–410.
[10] Record, W. Va. Geol. Surv., Reports, vol. 1, p. 288.
[11] Ibid., pp. 286–287.
[12] Record, Ohio Geol. Surv., Reports, 1888, vol. 6, pp. 201–202.
[13] Ibid., pp. 404–406.
[14] Ibid., p. 236.
[15] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 269–270.
[16] Ibid., pp. 320, 361.
[17] Ibid., p. 360.
[18] Ibid., pp 288–289.
[19] Ibid., pp. 294–295.
[20] Ibid., p. 346.
[21] Ibid., pp. 367–368.
[22] Ibid., pp. 654–655.
[23] Ibid., pp. 439–440.
[24] Ohio Geol. Surv., Report, 1888, vol. 6, p. 218.
[25] Record, ibid., pp. 217, 266–267.
[26] Ibid., Report for 1890, pp. 244–245.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Napoleon [1]	Henry	1,889			+3	For gas; salt water at 1,889 feet.
Nelsonville [2]	Athens	570-950				Many salt wells; one small gas well.
Nevada [3]	Wyandot	2,000				Nothing but salt water.
Newark [4]	Licking	1,449-2,385				Several gas wells; small flows.
Newburg [5]	Cuyahoga	3,000	5¾			Some gas; much salt water.
New Carlisle [6]	Clark	1,060				For gas; unsuccessful.
New Lisbon [7]	Columbiana	1,350-1,370				Gas wells.
New London [8]	Huron	998-1,030				Three wells; nothing found except salt water.
New Vienna [9]	Clinton	1,785				Salt water at 1,785 feet.
Niles [10]	Trumbull	780-900				Two borings for gas; unsuccessful.
North Baltimore [11]	Wood	1,104¼-1,295				Two gas and oil wells.
Do. [12]	do	1,190				
North Bend	Hamilton	1,350	5	200	+30	Good water.
Norwalk [13]	Huron	2,304				
Do	do	2,725	5¾			For oil or gas; unsuccessful.
Oak Harbor [14]		1,326-1,335				Three gas wells.
Oberlin	Ottawa	700				For oil or gas; unsuccessful.
Osborn	Greene	990				Unsuccessful.
Ottawa [15]	Putnam	1,314-1,365				Two oil and gas wells; small product; much salt water.
Oxford [16]	Butler	1,365				Shale gas and sulphur water only.
Painesville [17]	Lake	700-1,390				Several gas wells.
Patterson (2 miles south of). [18]	Hardin	1,330				Gas at 835 feet; large flow of water; unsuccessful.
Patterson (2 miles west of). [19]	do	1,300				Large flow of gas; also large flow of water.
Perrysburg [20]	Wood	+1,600				Several gas wells.
Piketon	Pike					
Pike Township [21]	Clarke	1,380				For gas; unsuccessful.
Piqua [22]	Miami	1,673				Do.
Plain City [23]	Madison	1,530-2,000	8		+13	Two wells; large flows of fine water from 350, 600, and 900 feet.
Plymouth [24]	Richmond	742				
Do. [25]	do	3,020				Salt and sulphur water at 850 feet.
Pomeroy	Meigs	1,550		20	−500	Salt well; some oil and gas.
Do	do	1,100				Several salt wells; flowed originally.
Do. [26]	do	767				
Pemberville	Wood					Unsuccessful.
Portage (vicinity) [27]	do	1,177				Do.

[1] Record, Ohio Geol. Surv., Report 1888, vol. 6, pp. 252-253.
[2] Ibid., p. 398.
[3] Ibid., p. 203.
[4] Ibid., pp. 317, 370-372.
[5] Record, Mich. Geol. Surv., 1881-1893, p. 73; Ohio Geol. Surv., Report, 1888, vol. 6, pp. 351-355; Ohio Geol. Surv., Report, vol. 1, pp. 352-355.
[6] Ohio Geol. Surv., Report, 1888, vol. 6, p. 280.
[7] Record, Ohio Geol. Surv., Report, vol. 6, 1888, p. 404.
[8] Ibid., pp. 440, 348-350.
[9] Ibid., pp. 296-297.
[10] Ibid., p. 401.
[11] Ibid., pp. 228-229; Pa. 2d Geol. Surv., Report for 1886, p. 786.
[12] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 228.
[13] Ibid., pp. 440-441.
[14] Ibid., pp. 210-211.
[15] Ibid., p. 241.
[16] Ibid., p. 294.
[17] Ibid., pp. 427-428.
[18] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 221-222.
[19] Ibid., p. 222.
[20] Ibid., pp. 225, 788.
[21] Ibid., p. 280.
[22] Ibid., p. 273.
[23] Ibid., Report 1890, p. 246; U. S. Geol. Surv., 19th Annual Report, 1897-98, p. 663.
[24] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 315.
[25] Ibid., pp. 302-303.
[26] Ibid., p. 397.
[27] Ohio Geol. Surv., Report 1888, vol. 6, pp. 164 165, 228.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Portage (vicinity) [1]	Wood	1,134				Unsuccessful.
Do.[1]	do					Large flow of gas.
Port Clinton [2]	Ottawa	+1,660				No product.
Portsmouth [3]	Scioto	2,000				No product, but salt water at 1,000 feet.
Prospect [4]	Marion	1,650				No product.
Quaker City [5]	Guernsey	1,347				Gas well.
Do	do	1,352				
Radcliff	Vinton	700 or 800				Water and gas.
Rarden	Scioto	1,710	10		—510	Water.
Rawson [6]	Hancock	1,337				For gas or oil; found salt water only.
Richland Furnace	Vinton					Gas well.
Ripley	Brown					No product.
Risingsun	Wood					Only small flow of oil.
Rockport [7]	Cuyahoga	527-1,335				Two gas wells; small flows.
Rutland Township	Meigs	1,560		10-25	—500	Salt water only.
Sabina	Clinton					
St. Henry [8]	Mercer	1,160-1,183				Gas well.
St. Marys [9]	Auglaize	1,230				Salt water only.
Do.[10]	do	1,132-1,225				Several oil wells.
Do.[10]	do	1,092-1,138				Several gas wells; large flows.
St. Paris [11]	Champaign	+1,000				Two unsuccessful borings.
Salem [12]	Columbiana	800-810+				Do.
Do	do	2,930				Unproductive.
Salem Township [13]	Wyandot	1,323				Small flow of oil.
Sandusky [14]	Erie	2,260				Some oil, gas, and salt water.
Saline Township [15]	Jefferson	1,105				Unproductive.
Sardis (SW of) [16]	Monroe	1,815				Oil well.
Sciotoville	Scioto	800				Unsuccessful.
Sevenmile	Butler	1,220	8		—6	Salt water and some gas.
Sheffield [17]	Lorain	720				Bored for oil; some gas found; unsuccessful.
Shelby [18]	Richland	1,480-1,796				Small flow of gas: 2 wells.
Sidney [19]	Shelby	1,205-1,250				Several gas wells; much salt water at 1,445 feet.
Somerset [20]	Perry	2,850			—400	Salt water at 2,850 feet.
South Kingsville [21]	Ashtabula	1,200				Gas well: some oil.
South Olive	Noble					Unproductive.
South Toledo [22]	Lucas	+1,012				Do.
Springfield [23]	Clarke	1,140-1,200				Several wells; unsuccessful.
Spring Valley [24]	Greene	1,500				Unsuccessful.
Steubenville [25]	Jefferson	1,230				Transient gas supply.
Do.[26]	do	2,519				
Stuartsville Township. [27]	Hancock	450				Oil wells.
Stryker	Williams	860				Mineral water at 230 feet.
Sunbury [28]	Delaware	2,530				
Tiffin [29]	Seneca	1,467-1,494				Several wells; large flow of gas; some oil.

[1] Ohio Geol. Surv., Report 1888, vol. 6, pp. 164-165, 228.
[2] Ibid., p. 212.
[3] Ibid., p. 395.
[4] Analysis, ibid., pp. 270-271.
[5] Record, ibid., pp. 324, 381-382.
[6] Ibid., p. 217.
[7] Record, Ohio Geol. Surv., Report 1888, vol. 6, pp. 432-434.
[8] Ibid., pp. 260-262.
[9] Ibid., pp. 255-258.
[10] Ibid., pp. 255-258.
[11] Ibid., pp. 276-277.
[12] Ibid., pp. 403-404, 452.
[13] Record, Pa. 2d Geol. Surv., Ann. Report for 1886, part 2, pp. 785-786.
[14] Record, Michigan Geol. Surv., 1881-1893, p. 83; Ohio Geol. Surv., Report, 1888, vol. 6, pp. 194-196.
[15] Record, Pa. 2d Geol. Surv., Report II, p. 282.
[16] Record, W. Va. Geol. Surv., Reports, vol. 1, pp. 356-357.
[17] Record, Ohio Geol. Surv., Report, 1888, vol. 6, p. 437.
[18] Ibid., pp. 316, 364-365.
[19] Ibid., pp. 264-266.
[20] Ibid., Report 1890, p. 247.
[21] Ibid., 1888, vol. 6, pp. 423-424.
[22] Ibid., p. 225.
[23] Ibid., pp. 278-280.
[24] Ibid., p. 291.
[25] Ibid., pp. 336-337.
[26] Record, Pa. 2d Geol. Surv., Ann. Report for 1886, part 2, p. 784.
[27] Ohio Geol. Surv., Report, 1890, pp. 219-220.
[28] Ibid., 1888, vol. 6, p. 283.
[29] Record, ibid., pp. 197-201.

OHIO—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Tiffin (vicinity of)[1]	Seneca	1,505-1,753				Several borings; all unsuccessful.
Tinney (south of)	Sandusky	1,220	8-5⅝		—10	Gas, oil, and salt water.
Tippecanoe[2]	Miami	1,025				Small flow of gas.
Toledo[3]	Lucas	1,425				Several borings for gas and oil; unsuccessful.
Tontogany (2½ miles southeast).	Wood	1,425	8-5⅝		—30	Some salt water, oil, and gas.
Toronto (4 miles west).[4]	Jefferson	1,455				For oil; unsuccessful.
Troy[5]	Miami	1,170				Some gas at 510, 680, and 880 feet.
Uniopolis	Auglaize					Very small flow of gas; abandoned.
Upper Sandusky[6]	Wyandot	1,340-1,347½				Two borings for oil or gas; unsuccessful.
Urbana[7]	Champaign	1,307-1,350				Very small showing of gas.
Vanlue[8]	Hancock	1,294				Small flow of gas.
Vanwert[9]	Vanwert	1,240				Very small flow of gas.
Vinton Township[10]	Vinton	490-1,057	10-5⅝			Gas, oil, and salt water.
Wakeman	Huron	3,000				For oil; found salt water only at 1,950 feet.
Wapakoneta[11]	Auglaize	1,600				For oil or gas; salt water only.
Washington[12]	Fayette	1,850				For gas or oil; found salt water only.
Waterville[13]	Lucas	1,153				Small flow of gas.
Wauseon[14]	Fulton	+2,158				Oil at 2,158 feet.
Wellington[15]	Lorain	1,030-1,050				Several small gas wells.
Westerville[16]	Franklin	+2,300				
Westminster[17]	Allen	1,400				For oil or gas; unsuccessful.
West Newton[18]	do	1,440				
Weston[19]	Wood	1,575				Oil, gas, and sulphur water.
Whartonsburg[20]		1,427				For oil or gas; unsuccessful.
Williamsburg	Clermont	660	6			Small flow of gas.
Do	do	660	6			Unsuccessful.
Willoughby[21]	Lake					Several small gas wells.
Wilmington[22]						
Woodville[23]	Sandusky	1,460				For oil or gas; only salt water found.
Wooster[24]	Wayne	1,805-2,000				Three borings for oil or gas; unsuccessful.
Xenia[25]	Greene	1,200				For oil or gas; unsuccessful.
Youngstown[26]	Mahoning	2,480				For gas or oil; unsuccessful.
Zanesville[27]	Muskingum	1,098-2,019				Three wells; some oil.

[1] Record, Ohio Geol. Surv., Report 1890, pp. 784-785.
[2] Ohio Geol. Surv., Report, 1888, vol. 6, p. 274.
[3] Record, ibid., pp. 208-209; Michigan Geol Surv., 1881-1893, p. 85.
[4] Pennsylvania 2d Geol. Surv., Report I5, p. 236.
[5] Ohio Geol. Surv. Report, 1888, vol. 6, p. 274.
[6] Ibid., p. 202.
[7] Record, ibid., p. 275.
[8] Ibid., p. 219.
[9] Ibid., pp. 239-240.
[10] Ibid., p. 394.
[11] Ibid., p. 254.
[12] Record, Ohio Geol. Surv., Report 1888, vol. 6, p. 291.
[13] Ibid., p. 225.
[14] Ibid., pp. 246-247.
[15] Ibid., pp. 348-349.
[16] Ibid., p. 283.
[17] Ibid., p. 220.
[18] Ibid., p. 220.
[19] Ibid., pp. 223-224.
[20] Ibid., p. 203.
[21] Ibid., p. 428.
[22] Ibid., pp. 296-297.
[23] Ibid., pp. 213-214.
[24] Record, Ohio Geol. Surv., Report, 1888, vol. 6, pp. 361-363.
[25] Ibid., pp. 289-290.
[26] Ibid., pp. 321, 402-403.
[27] Ibid., pp. 372-375.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN OHIO.

Report of the Geological Survey of Ohio, Volume VI, Economic Geology, 831 pages, plates, Columbus, 1888.

First Annual Report of the Geological Survey of Ohio (third organization), by Edward Orton, State geologist, 323 pages, plates, Columbus, 1890.

Water Resources of Indiana and Ohio, by Frank Leverett, U. S. Geological Survey, Eighteenth Annual Report, 1896–97, part 4, pp. 423–559, plates, Washington, 1897.

The Rock Waters of Ohio, by Edward Orton, U. S. Geological Survey, Nineteenth Annual Report, 1897–98, part 4, pp. 633–717, plates, Washington, 1899.

OKLAHOMA.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Fort Reno	Canadian	1,200				
Oklahoma City		780				For oil or gas; unsuccessful.
Pawhuska	Osage	1,700				Oil well.
Mangum	Greer	500				For oil; unsuccessful.
Do	do	400				Abandoned.

OREGON.

Baker City	Baker	400		Many.		
Blalock	Gilliam	400				Unsuccessful.
Bliss Water Station		418	4–3¼	42	+10	Water tepid.
Burns	Harney	750	8			Abandoned. Only a very small flow at 300 feet.
Cleft Water Station		425	3	+28	+10	Water tepid.
Fort Stevens	Clatsop	400				Unsuccessful.
Do	do	800				Do.
Heppner	Morrow	650				
Portland	Multnomah	1,850				
The Dalles	Wasco	1,020	4¼–1¾			Bored for oil; no water below 350 feet.

PENNSYLVANIA.

Abbot Township	Potter	2,100				Oil boring; unsuccessful.
Do[1]	do	2,029				Small gas well.
Allegheny	Allegheny	1,760				Salt well.
Allegheny Township.[2]	Butler	1,055–1,408				Oil and gas wells.
Do.[3]	Venango	850				For oil; unproductive.
Do.[4]	Westmoreland.	1,250–2,847				For oil or gas; mostly unproductive.
Allen Township[5]	Washington	2,060				Gas well.
Altoona	Blair	2,066				Abandoned.
Amity Township	Erie	500–630				Several oil and gas wells.
Amwell Township[6]	Washington	2,385				For oil or gas; unproductive.
Ashland (vicinity)	Schuylkill	1,830	2	139	Flows.	Temp. 54°.
Ashland Township[7]	Clarion	1,128				For oil or gas; unproductive.

[1] Records, Pa. 2d Geol. Surv., Ann. Rept. for 1885, pp. 85–86.
[2] Ibid., Vol. II., pp. 238–240.
[3] Ibid., Vol. I[4], pp. 58–59.
[4] Ibid., Vol. I[5], pp. 211–215; Vol. II, pp. 277–278.
[5] Ibid., pp. 301–302
[6] Ibid., pp. 307–308.
[7] Ibid., p. 230.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Baden (1 mile north)[1]	Beaver	1,366				For oil or gas.
Barnet Township[2]	Forest	2,428				For oil or gas; unsuccessful.
Beaver Falls[3]	Beaver	2,330				Do.
Beaver Falls (2 miles above).[4]	do	982				Gas well.
Beaver Township[5]	Clarion	1,001-1,200				For oil or gas.
Belle Vernon[6]	Fayette	2,005				Small gas well.
Benezette[7]	Elk	721	3			For oil or gas; abandoned.
Black Ash[8]	Crawford	777				Do.
Blacklick (vicinity)[9]	Indiana	1,728				Do.
Black's Siding[10]	Venango	1,650				For oil or gas; unproductive.
Blacksville[11]	Greene	500?				For oil.
Blairsville[12]	Westmoreland.	2,060				For oil or gas; abandoned.
Bloomfield Township.[13]	Crawford	590-1,000				Several oil wells.
Bradford[14]	McKean	1,085				For oil.
Bradford (vicinity)[15]	do	1,010-1,719				Numerous oil and gas wells.
Brady Township[16]	Butler	1,458-1,596				For oil.
Bradys Bend	Armstrong	+1,089				Oil and gas well.
Bradys Bend Township.[17]	do	1,100-1,260				For oil.
Bridgeville (vicinity).[18]	Allegheny	2,250				
Bridgewater (near)	Beaver					For gas; small supply.
Brookston	Forest	2,200				For oil or gas; unsuccessful.
Brookville[19]	Jefferson	3,100				For oil or gas; unproductive.
Do.[20]	do	1,700				Gas well.
Brookville Borough[21]	do	2,430				Do.
Brownsville[22]	Fayette	+2,106				Do.
Brush Run[23]	Clarion	1,047-1,636				Oil and gas wells.
Brushton Station	Allegheny	1,615				Unsuccessful.
Bryn Mawr	Montgomery	550	8	83	−310	
Do	do	600	6	120		
Burrell Township[24]	Westmoreland.	2,500				
Do.[25]	do	1,850				For oil or gas; abandoned
Butler[26]	Butler	3,055				Do.
Do	do	1,500-1,950				Several oil and gas wells.
Butler (3 miles south)	do	3,008	5			
Do.[27]	do	1,500-1,795				Gas and oil wells.
Butler Township[28]	do	1,524-1,637				For oil.
Cambria Mill[29]	Cambria	653(?)				Gas well.
Cameron Station (½ mile northeast).[30]	Cameron	971				For oil.
Cannonsburg (vicinity).[31]	Washington	1,763-2,502				Numerous oil and gas wells; some unproductive.
Canton Township[32]	do	2,727				For oil or gas.
Carlisle (1½ miles SE)	Cumberland	864	5-4½			
Carlisle (5 miles west).	do	420	5-4½			

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 232.
[2] Ibid., p. 154.
[3] Ibid., Vol. III, pp. 401-404.
[4] Ibid., Vol. I[4], pp. 142-143.
[5] Ibid., Vol. II, pp. 228-229.
[6] Ibid., Ann. Rept., 1886, part 2, pp. 778-779.
[7] Ibid., Vol. I[4], pp. 133-134; Vol. R R, p. 248.
[8] Ibid., Vol. I[5], p. 186.
[9] Ibid., p. 168.
[10] Ibid., pp. 184-185.
[11] Ibid., Vol. K, pp. 108-109.
[12] Ibid., Vol. I[5], pp. 224-225.
[13] Records, Pa. 2d Geol. Surv., Reports, Vol. Q, pp. 224-226; Vol. II, pp. 273-274; Vol. I[4], p. 119.
[14] Ibid., Vol. I[4], pp. 97-103.
[15] Ibid., Vol. I[4], p. 89; Vol. R, pp. 287-290.
[16] Ibid., Vol. G[4], pp. 150-151; Vol. III, pp. 418-419.
[17] Ibid., Vol. II, pp. 258-259.
[18] Ibid., Vol. I[5], p. 272.
[19] Ibid., pp. 163-164.
[20] Ibid., Vol. I[4], p. 139.
[21] Ibid., Ann. Rept., 1886, part 2, p. 778.
[22] Ibid., Vol. I[5], pp. 317-318.
[23] Ibid., pp. 235-236.
[24] Ibid., pp. 212-213.
[25] Ibid., Ann. Rept. for 1886, part 2, pp. 686-687.
[26] Ibid., Vol. I[5], pp 193-194.
[27] Ibid., pp 209-210
[28] Ibid., Ann Rept. for 1886, part 2, pp. 711-718.
[29] Ibid., Vol. HH, pp. 176-180.
[30] Ibid., Vol. RR, part 2, p. 23; vol. G[4], p. 138.
[31] Ibid., Vol. I[5], pp. 281-297.
[32] Ibid., pp. 279-280.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Carmichaels (vicinity).[1]	Greene	2,432				For oil or gas.
Carpenters Station (near).[2]	Westmoreland.	1,541				Do.
Chambersburg	Franklin	+400				
Chambersburg (2 miles west).	do	600	6		−17	Water at 420 feet.
Cherry Grove Township.[3]	Warren	1,548-2,004				Several oil and gas wells; some unproductive.
Cherry Tree Borough.[4]	Cambria	653				Gas well.
Church Run[5]	Crawford	415-700				Several oil wells.
Clarion[6]	Clarion	1,238-1,367				Several oil wells; one unproductive.
Clearfield (2 miles southwest).[7]	Clearfield	2,900				For oil or gas; unproductive.
Clearfield Township).[8]	Butler	1,558-1,925				Several oil and gas wells; one unsuccessful.
Clinton Township[9]	Venango	836-1,266				Several oil wells; mainly productive.
Cooksburg[10]	Forest	2,100-2,726				For oil or gas, unsuccessful.
Cooksburg (vicinity).[11]	Clarion	843-2,050				For oil or gas, one unproductive.
Collier Township[12]	Allegheny	2,400				Gas well.
Concord Township[13]	Crawford	845				Oil and gas well.
Conneautville (1 mile below).[14]	do	750				For oil or gas.
Cornplanter Township.[15]	Venango	451-924				Do.
Corry[16]	Erie	2,340				Gas and oil well.
Corydon (1 mile from).[17]	McKean	1,532-1,601				Gas wells.
Corydon Township	Warren	720				For oil.
Coudersport[18]	Potter	2,100				Small gas well.
Cranberry Township.[19]	Venango	600-1,506				Numerous oil and gas wells, mainly productive.
Crawford Township	Clinton	458				Coal prospect, unsuccessful.
Crescent Township[20]	Allegheny	2,106				For oil or gas, unproductive.
Cresson[21]	Cambria	677				For oil.
Criswell (vicinity)[22]	Armstrong	1,394-1,618				Oil and gas wells.
Darlington[23]	Beaver	2,444				For oil or gas, unproductive.
Degolia (near)[24]	McKean	1,404				For oil or gas.
Delano	Schuylkill	515	2			Coal prospect.
Demmler	Allegheny	1,600				For oil or gas, abandoned.
Dennis Run[25]	Warren	426-632				Several oil and gas wells.
Dicksonburg	Crawford	680?				Oil well.
Dixmont[26]	Allegheny	1,802				Oil and gas well.
Donegal Township[27]	Butler	1,565-1,740				Many oil and gas wells.
Doylestown	Bucks	750				
Dubois Station[28]	Clearfield	3,020				For oil or gas, unproductive.
Dunkard Township	Greene					Several oil wells.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 315-316.
[2] Ibid., Ann. Rept. for 1886, part 2, pp. 725-726.
[3] Ibid., Vol. I[4], pp. 26-27, 375-376.
[4] Ibid., p. 146.
[5] Ibid., Vol. II, pp. 66-69.
[6] Ibid., Vol. I[5], pp. 157-159; Vol. III, pp. 413-414.
[7] Ibid., Vol. I[5], pp. 166-167.
[8] Ibid., Ann. Rept. for 1886, part 2, p. 178; Vol. II, pp. 266-268.
[9] Ibid., Vol. II, pp. 219-222.
[10] Records, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 159-161.
[11] Ibid., Vol. I[4], pp. 140-141.
[12] Ibid., Vol. I[5], pp. 261-262.
[13] Ibid., Vol. Q[4], p. 212.
[14] Ibid., Vol. Q[4], pp. 216, 234-236.
[15] Ibid., Vol. I[4], pp. 59-61.
[16] Ibid., Vol. I[4], p. 228.
[17] Ibid., Vol. I[4], pp. 259-261.
[18] Ibid., Ann. Rept., 1886, part 2, pp. 775-776.
[19] Ibid., Vol. II, pp. 203-207, 210-214; Vol. I[4], pp. 62-63.
[20] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 264-265.
[21] Ibid., Vol. HH, p. 30.
[22] Ibid., Vol. II, pp. 253-258.
[23] Ibid., Ann. Rept., 1886, part 2, pp. 780-781.
[24] Ibid., Vol. I[4], p. 90.
[25] Record, Am. Phil. Soc., Proc., vol. 16, pp. 367-370.
[26] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 257-258.
[27] Ibid., pp. 199-203; Vol. II, pp. 263-265.
[28] Ibid., Vol. I[5], pp. 165-166.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Eagle Station	Delaware	1,700		Few.		
East Bethlehem Township.[1]	Washington	604				Salt well, abandoned.
East Brookside	Schuylkill	585	8			Oil well.
East Deer Township[2]	Allegheny	1,194-1,243				Several gas wells, one abandoned.
Easton	Northampton.	500		105	−43	
East Pike Run Township.[3]	Washington	1,950				Gas well.
Ebensburg	Cambria	1,000	5¾	Many.	No flow.	
Edenburg[4]	Clarion	1,268				Good oil well.
Edenburg (1 mile southeast).[5]		1,046				
Eldred Township[6]	Warren	415-481				Oil and gas wells.
Elkland	Tioga					For oil or gas.
Elklick	Somerset	+1,500				
Do	do	2,900				For oil.
Elk Township[7]	Clarion	977-1,450				Several oil or gas wells, some unproductive.
Do.[8]	Warren	1,500				For oil, abandoned.
Elrod	Allegheny	±1,500				For oil or gas, abandoned.
Do.[9]	do	1,486			Flows	For oil or gas, unsuccessful.
Elrod (1 mile north)	do	1,510				For gas, abandoned.
Elrod Township[10]	Warren	588-914				For oil or gas.
Emelton (vicinity)[11]	Venango	720-1,000				Numerous oil wells, mainly productive.
Emporium[12]	Cameron	1,410				For oil.
Do	do	+400				
Emporium (4 miles northwest).[13]	do	1,607				For oil or gas, unproductive.
Enterprise[14]	Warren	474-487				Several oil wells.
Enterprise (vicinity).[15]	do	462-800				Do.
Erie[16]	Erie	4,460				For oil or gas, abandoned.
Do.[17]	do	1,250-1,418				Gas wells.
Do	do	470-800				Numerous gas and oil wells.
Fairoaks[18]	Beaver	1,645				Small oil well.
Fairoaks (vicinity)[19]	do	1,606				Gas well.
Falls Creek Station (near).[20]	Jefferson	3,040				Do.
Fairview Township[21]	Butler	1,421-1,694				Numerous oil and gas wells.
Do.[22]	Erie	700-1,000				Several gas wells.
Farrentown[23]	Armstrong	1,140-1,166				Several oil and gas wells.
Fawn Township		1,147-1,550				Several good gas wells.
Forest City	Wayne					Coal prospect.
Foresthill	Union	480			Flows.	Sulphur water.
Fort Hunter	Dauphin	2,675	6			Abandoned.
Forward Township[24]	Butler	1,553-1,683				Oil and gas wells.
Foxburg[25]	Armstrong	805-944				Small oil wells.
Franklin (½ mile northeast).[26]	Venango	490			Flows.	Good oil well.
Franklin (8 miles south).[27]	do	3,880				For oil or gas, unproductive.
Franklin Township[28]	Washington	2,608				For oil or gas, abandoned.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. K, pp. 178-179.
[2] Ibid., Vol. I[5], pp. 237-238.
[3] Ibid., pp. 302-303.
[4] Ibid., Vol. I[4], pp. 139-140.
[5] Ibid., Vol. II, p. 229.
[6] Ibid., Vol. I[4], pp. 52-53.
[7] Ibid., Vol. II, pp. 230-232; Vol. III, pp, 415-416.
[8] Ibid., Vol. I[4], p. 30.
[9] Record, Pa. 2d Geol. Surv., Report for 1886, part 2, pp. 667-668.
[10] Ibid., Vol. II, pp. 195-196.
[11] Ibid., pp. 222-225.
[12] Ibid., Vol. G[4], p. 140.
[13] Ibid., p. 141.
[14] Ibid., Vol. II, pp. 65-66.
[15] Record, Am. Phil. Soc., Proc., vol. 16, pp. 367-369.
[16] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 187-192.
[17] Ibid., Vol. I[4], pp. 122, 290.
[18] Ibid., Vol. I[5], pp. 232-233.
[19] Ibid., p. 233.
[20] Ibid., p. 164.
[21] Records, Pa. 2d Geol. Surv., Reports, Vol. II. pp. 246-262.
[22] Ibid., Vol. Q[4], pp. 262-263.
[23] Ibid., Vol. II, pp. 242-243.
[24] Ibid., Vol. I[5], p. 208.
[25] Ibid., Vol. II, pp. 237-238.
[26] Ibid., Vol. I[4], p. 65.
[27] Ibid., Vol. I[5], pp. 185-186.
[28] Ibid., p. 279.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Franklin Township[1]	Allegheny	1,905-2,150				Several oil or gas wells.
Do.[2]	do	1,492-±1,500				For oil or gas.
Gaines[3]	Tioga	1,345				For oil or gas, abandoned.
Gallagher Township	Clinton	3,525				
Georgetown[4]	Beaver	1,430				For oil or gas, abandoned.
German Township[5]	Fayette	1,196				Gas well.
Gerties Run[6]	Allegheny	±1,600				For oil or gas, abandoned.
Gibsonia (½ mile west).[7]	do	2,017				For oil or gas.
Girard Township[8]	Erie	980				For oil, unsuccessful.
Good Intent (2½ miles southwest).[9]	Washington	2,720				For oil or gas, unproductive.
Great Belt City (vicinity).[10]	Butler	1,875				
Greece City (3 miles west).[11]	do	1,500				Do.
Greece City (vicinity).[12]	do	1,423-1,530				Several oil and gas wells.
Greene Township	Greene					Oil and gas well.
Greenfield	Erie	780				Large gas well.
Greensboro[13]	Greene	668				Oil well.
Greensburg (4 miles southwest).[14]	do	769				Do
Hamilton Township[15]	McKean	2,011				Oil well.
Hamlin Township[16]	do	2,315-2,400				Several oil wells; some unproductive.
Do.[17]	do	1,613-1,768				Several oil wells; one abandoned.
Hammersley Fork	Clinton	—1,800				For oil.
Hanover Township[18]	Beaver	1,644				
Harrisburg	Dauphin	2,800	6			For gas. Abandoned.
Do	do	+400				Two wells.
Harrison Township[19]	Allegheny	1,109-1,200				Several gas wells.
Do.[20]	Potter	1,995				
Harrisville (vicinity.)[21]	Butler	880-1,367				For gas or oil.
Hazleton	Luzerne	482-690	2			Coal prospects.
Hebron[22]	Potter	1,286				For oil.
Hempfield Township.[23]	Westmoreland.	1,255				Gas well.
Herman[24]	Butler	1,784-1,901				Several oil and gas wells.
Hickory	Washington					Gas well.
Hickory (2½ miles southwest).[25]	do	2,245				Large gas well.
Hickory (2 miles southeast).[26]	do	2,205				Large flow of gas.
Hickory (vicinity)[27]	do	700-1,151				Several large gas wells.
Highland Township[28]	Elk	2,095-2,448				Many oil and gas wells; some abandoned.
Hollenback	Bradford	600				
Homestead (vicinity).[29]	Allegheny	1,744				For oil or gas.
Homewood Station	Beaver	1,500(?)				Do.

[1] Records, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 251-254.
[2] Ibid., Vol. I[4], p. 144.
[3] Ibid., Vol. I[5], pp. 147-148.
[4] Ibid., p. 233.
[5] Ibid., pp. 321-322.
[6] Ibid., Ann. Rept. for 1886, part 2, pp. 742-744.
[7] Ibid, Vol. I[5], p. 242.
[8] Ibid., Vol. Q[4], p. 259.
[9] Ibid., Vol. I[5], pp. 305-306.
[10] Ibid., Vol. I[4], p. 138.
[11] Ibid., p. 141.
[12] Ibid., Vol. II, pp. 247-248.
[13] Ibid., Ann. Rept. for 1886, part 2, p. 774.
[14] Ibid., Vol. I[4], p. 145.
[15] Record Pa. 2d Geol. Surv., Reports, Vol. R, pp. 266-267.
[16] Ibid., Vol. I[5], pp. 151-152.
[17] Ibid., Vol. R, pp. 179-182; Vol. I[4], pp. 111-113.
[18] Ibid., Vol. I[5], pp. 235-236.
[19] Ibid., Ann. Rept. for 1886, part 2, pp. 684-686.
[20] Ibid., Vol. G[3], pp. 80-81.
[21] Ibid., Ann. Rept. for 1886, part 2, pp. 718-719.
[22] Ibid., Vol. G[3], p. 79.
[23] Ibid., Vol. I[5], p. 223.
[24] Ibid., pp. 195-197.
[25] Ibid., Ann Rept. for 1886, part 2, pp. 754-755.
[26] Ibid., pp. 769-772.
[27] Ibid., pp. 758-760; Am. Phil. Soc., Proc., vol. 16, p. 489.
[28] Ibid., Pa. 2d Geol. Surv., Ann. Rept. for 1886, part 2, pp. 707-709; Vol. I[5], p. 155.
[29] Ibid., pp. 744-746.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Homewood Station (vicinity).[1]	Beaver	925				For oil or gas.
Honesdale (5 miles from).	Wayne	2,500				Two oil wells; abandoned.
Honesdale (6 miles north).[2]	do	1,505				For oil.
Hopewell Township[3]	Beaver	1,490-1,572				
Horatio	Jefferson	543			−10	
Howe Township[4]	Forest	1,475-1,985				Several oil wells.
Do.(?)[5]	do	2,233				Gas well.
Hulton Station (near)	Allegheny					For gas; unsuccessful.
Humes Station (near).[6]	Clinton	1,821				For oil or gas; unproductive.
Huntingdon	Huntingdon	400				Several wells.
Hyner Station (near)[7]	do	1,187				For oil.
Independence Township.[8]	Beaver	+1,223				For oil or gas; unproductive.
Irwin	Westmoreland.	4,380				
Do.[9]	do	2,340				Do.
Jacks Run[10]	Allegheny	1,724		Many.	Flows.	Fresh water at 1,600 feet.
Jackson Township[11]	Venango	688				Oil well.
Jamestown[12]	Mercer	1,063				Oil and gas well.
Jefferson[13]	Greene	2,658				
Jefferson Center[14]	Butler	1,732				Oil well.
Jefferson Township[15]	Allegheny	2,014				Gas well.
Jenks Township[16]	Forest	400-1,003				Several gas or oil wells; unproductive.
Do.[17]	do	1,310-2,505				Several wells; mainly unproductive.
Jermyn	Lackawanna	780	6	25		
Johnsonburg Station.[18]	Elk	2,510				Large gas well.
Johnstown[19]	Cambria	2,856				For oil or gas; unproductive.
Johnstown (4 miles west).[20]	do	2,500				Do.
Jones Township[21]	Elk	1,335-1,756				Two oil wells; one abandoned.
Karns City (¼ mile south).[22]	Butler	1,454				
Kingsley Township[23]	Forest	2,200				For oil or gas; unproductive.
Kinzua Township[24]	Warren	1,048-2,285				Several oil wells; mainly unproductive.
Knox Township[25]	Jefferson	1,608-2,000				Moderate gas wells.
Lafayette Township.[26]	McKean	2,111-2,490				Several oil and gas wells.
Lardens Mills[27]	Butler	1,140				Gas well.
Latrobe[28]	Westmoreland.	1,980				For oil or gas.
Lawrenceburg (south of).[29]	Armstrong	1,017				
Layton Station[30]	Fayette	2,100				For oil or gas; unproductive.
Leboeuf	Erie	780				Oil and gas well.
Limestone (3 miles south).	McKean	1,130				Oil well.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. QQ, pp. 250-251.
[2] Ibid., Vol. G^6, pp. 91-93.
[3] Ibid., Vol. I^5, pp. 234-235.
[4] Ibid., Vol. I^4, pp. 79-81; Ann. Rept. for 1886, part 2, p. 700.
[5] Ibid., Ann. Rept. for 1886, part 2, pp. 700-701.
[6] Ibid., Vol. I^5, p. 197.
[7] Ibid., Vol. G^4, pp. 131-134.
[8] Ibid., Ann. Rept. for 1886, part 2, pp. 779-780.
[9] Ibid., Vol. I^5, pp. 221-222.
[10] Ibid., Ann. Rept. for 1886, part 2, pp. 748-749.
[11] Ibid., Vol. II, p. 201.
[12] Ibid., pp. 274-275.
[13] Ibid., Vol. I^5, pp. 314-315.
[14] Ibid., Ann. Rept. for 1886, part 2, pp. 716-717.
[15] Ibid., pp. 752-753.
[16] Ibid., Reports, Vol. I^4, pp. 81-83.
[17] Ibid., pp. 83-86; Ann. Rept. for 1886, part 2, pp. 702-705.
[18] Ibid., Ann. Rept. for 1886, part 2, pp. 710-711.
[19] Ibid., Reports, Vol. I^5, pp. 169-170.
[20] Ibid., pp. 170-171.
[21] Ibid., Vol. I^4, pp. 127-128.
[22] Ibid., Vol. II, pp. 262-263.
[23] Ibid., Ann. Rept. for 1886, part 2, pp. 703-704.
[24] Ibid., Vol. I^4, pp. 27-29.
[25] Ibid., Vol. I^5, pp. 162-163.
[26] Records, Pa. 2d Geol. Surv., Repts., Vol. I^5, pp. 152-53.
[27] Ibid., Vol. II., pp. 270-271.
[28] Ibid., Vol. I^5, pp. 223-224.
[29] Ibid., Vol. II., p. 243.
[30] Ibid., Vol. I^5, pp. 318-319.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Littlestown	Adams	500				
Little Washington	Washington					Two gas wells.
Lockhaven	Clinton	3,525	6¼			For oil or gas; unsuccessful.
Lottsville [1]	Warren	960–1,515				Two oil or gas wells; abandoned.
Lovelton (near)	Wyoming					Deep well.
Mahanoy City (near)	Schuylkill	1,130	2	Many.	Flows.	Temp. 51°.
Manchester [2]	York	1,520				For oil or gas.
Marienville (near) [3]	Forest	1,305				
Marion Township [4]	Butler	765				
Mars Station (near) [5]	do	1,900				For oil or gas; unproductive.
Marshall Township [6]	Allegheny	1,830				
Masontown [7]	Fayette	2,525				Gas well.
McCandless Township. [8]	Allegheny	2,110				For oil or gas.
McDonald [9]	Washington	2,342				Gas well.
McKeesport Borough	Allegheny	1,640				Do.
Meadville [10]	Crawford	900				Several oil wells in this vicinity.
Mercer (near) [11]	Mercer	1,702				Gas well.
Miam Hollow [12]	McKean	1,390				
Middlesex (near) [13]	Mercer	2,030				For oil or gas; unproductive.
Middlesex, West (1 mile south). [14]	do	3,484				Do. Do.
Middlesex Township. [15]	Butler	1,785–1,930				Several oil and gas wells.
Mill Creek Township. [16]	Clarion	2,323				For oil or gas; unproductive.
Millvale [17]	Allegheny	1,655				For oil or gas; unsuccessful.
Millville [18]	Clarion	2,280				Oil and gas well.
Monongahela [19]	Washington	2,152–2,218				Gas wells.
Moon Township [20]	Allegheny	1,800–2,337				Several oil and gas wells.
Do. [21]	Beaver	1,257–1,680				Several oil or gas wells.
Monroeville (1 mile southeast). [22]	Allegheny	1,798		Many.	Flows.	Fresh water.
Montana	Columbia	717–722	2			
Mount Carmel	Northumberland.	900	2			
Mount Morris (near). [23]	Greene	1,772				Oil well.
Murrysville [24]	Westmoreland.	1,337–1,440				Numerous oil and gas wells.
Murrysville (vicinity). [25]	do	1,312–1,465				Large oil field.
Neilltown (vicinity) [26]	Forest	780–995				Numerous oil and gas wells; some unproductive.
Neville Island [27]	Allegheny	1,686–1,837				Several oil and gas wells.
Newcastle [28]	Lawrence	2,700	5⅝			For oil or gas; unproductive.
Newcastle (vicinity)	do	1,912				Gas and oil well.
Do	do	700–900				Several wells.
New Sewickley Township. [29]	Beaver	1,820				For oil or gas; unproductive.
Newton Hamilton	Mifflin	800				Not in operation.
Nineveh (vicinity) [30]	Greene	2,970–3,221				Several wells.

[1] Records, Pa. 2d Geol. Surv., Repts., Vol. I[5], pp. 232–233.
[2] Ibid., Vol. II, pp. 278–279.
[3] Ibid., Vol. G[4], pp. 146–147.
[4] Ibid., Ann. Rept. for 1886, part 2, p. 720.
[5] Ibid., Vol. I[5], p. 210.
[6] Ibid., pp. 242–243.
[7] Ibid., pp. 322–323.
[8] Ibid., p. 254.
[9] Record, W. Va. Geol. Surv., Repts., Vol. 1, 1889, pp. 214–30.
[10] Pa. 2d Geol. Surv., Repts., Vol. Q[4], p. 175.
[11] Record, ibid., Vol. II., p. 275.
[12] Record, Pa. 2d Geol. Surv., Reports, Vol. I[4], p. 97.
[13] Ibid., Vol. I[5], pp. 229–230.
[14] Ibid., pp. 230–231.
[15] Ibid., Vol. II, p. 271; Vol. I[5], pp. 197–198; Vol. III, pp. 404–405.
[16] Ibid., Vol. II, pp. 232–234.
[17] Ibid., Ann. Rept. for 1886, part 2, pp. 741–742
[18] Ibid., Reports, Vol. III, pp. 411–412.
[19] Ibid., Vol. I[5], p, 301.
[20] Ibid., pp. 263–268.
[21] Ibid., Ann. Rept. for 1886, part 2, pp. 688–689.
[22] Ibid., pp. 746–747.
[23] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 316–317.
[24] Ibid., pp. 215–218.
[25] Ibid., Ann. Rept. for 1886, part 2, pp. 673–674, 721–724.
[26] Ibid., Reports, Vol. I[4], pp. 69–77.
[27] Ibid., Vol. I[5], pp. 258–260.
[28] Ibid., Vol. G[4], pp. 151–152; Vol. II, pp. 275–276.
[29] Ibid., Vol. I[5], pp. 231–232.
[30] Ibid., pp. 308–312.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
North Mahoning Township.	Indiana	2,615(?)				Gas well.
North Strabane Township.	Washington	1,800				Small gas well.
North Warren (near)[1]	Warren	475–965				Numerous gas and oil wells; some unproductive.
Do.[2]	do	1,200–1,400				Several oil and gas wells; unproductive.
Do.[3]	do	1,835				For oil; abandoned.
Oakdale Station (3 miles north).[4]	Allegheny	2,164				For oil or gas.
Oakland Township[5]	Venango	640				
O'Harra Township[6]	Allegheny	1,950–2,060				For oil or gas; unproductive.
Ohio Township[7]	do	1,715–2,240				Numerous gas and oil wells.
Oil City[8]	Venango	1,070				
Do.[9]	do	540–818				Several oil wells.
Oil Creek Township	Crawford	3,500				For oil.
Do.[10]	Venango	902–1,000				Several oil wells.
Olmstead (near)	McKean	1,040				Oil well.
Oneida Station (1½ miles east).[11]	Butler	2,135				Gas well.
Osterburg (2 miles northwest).	Bedford	800			+3	
Parker City[12]	Armstrong	850				Oil well.
Parker Township[13]	Butler	1,183–1,418				For oil.
Pennsburg	Montgomery	1,000				
Penn Township[14]	Allegheny	1,750				For oil or gas; unproductive.
Do.[15]	Butler	1,528–1,825				Numerous oil and gas wells; some good producers.
Do.[16]	Westmoreland.	2,495				Large gas well.
Do.[17]	do	1,580–1,690				Several large gas wells.
Perry Township[18]	Armstrong	801–950				For gas or oil.
Do.[19]	do	791				Oil and gas well.
Petroleum Center[20]	Venango	500–900				Numerous oil wells; mainly productive.
Petrolia (vicinity)[21]	Butler	1,400–1,631				Numerous gas and oil wells.
Philadelphia (Melrose).	Philadelphia	553	10-8	150	−6	
Philadelphia (Ambler Works).	do	500	6	250		
Philadelphia (Morocco Works).	do	500	6	500		
Philadelphia (N. & G. N. Taylor).	do	670	12	250		
Philadelphia (League Island).	do	600				
Philadelphia (Hog Island).	do	456				
Philadelphia (Twenty-fourth and Brown streets).	do	495	6	60		
Philadelphia (Thirteenth and Mount Vernon streets).	do	3,031	8	2,600		
Philadelphia (Seventh and Callow Hill streets).	do	452	8	150		

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 10–15.
[2] Ibid., pp. 11–13.
[3] Ibid., p. 12.
[4] Ibid., Vol. I[5], pp. 262–263.
[5] Ibid., Vol. II, p. 202.
[6] Ibid., Vol. I[5], pp. 239–241.
[7] Ibid., pp. 244–251.
[8] Ibid., Vol. III, p. 416.
[9] Record, Am. Philos. Soc., Proc., Vol. 16, pp. 482–487; Pa. 2d Geol. Surv., Reports, Vol. II, pp. 204–205.
[10] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 53–54.
[11] Ibid., Pa. 2d Geol. Surv., Ann. Rept., 1886, part 2, pp. 717–718.
[12] Ibid., Reports, Vol. II, p. 242.
[13] Ibid., pp. 243–246.
[14] Ibid., Ann. Rept. for 1886, part 2, pp. 749–750.
[15] Ibid., pp. 713–716; Vol. I[5], pp. 206–208.
[16] Ibid., pp. 219–220.
[17] Ibid., pp. 218–219; Ann. Rept. for 1886, part 2, pp. 724–725.
[18] Ibid., Vol. II, pp. 240–241.
[19] Ibid., Vol. III, pp. 416–417.
[20] Records, Am. Phil. Soc., Proc., vol. 16, pp. 470–477.
[21] Records, Pa. 2d Geol. Surv., Reports, Vol. II, pp. 260–261, 283–296.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Philadelphia (Crown and Willow streets).	Philadelphia	1,000	10	100		
Philadelphia (Fifteenth and Market streets).	do	500	8	100		
Philadelphia (108 South Broad street).	do	484	8	60		
Philadelphia (Broad street below Locust).	do	525	8	110		
Philadelphia (Amholt & Schaefer Brewing Co.).	do	1,500		50		
Pike Township [1]	Potter	1,835				For oil or gas; unproductive.
Do.[2]	do	1,500				For oil or gas; abandoned.
Pinegrove	Schuylkill	450	8	Many.	No flow.	
Pinegrove Township.[3]	Venango	1,869-2,060				Several oil wells.
Do.[4]	do	912-1,070				For oil.
Do.[5]	Warren	750-1,830				Several oil and gas wells; small production.
Pine Township [6]	Allegheny	2,010				Two gas and oil wells.
Do.[7]	Armstrong	1,410-1,693				Oil and gas wells.
Pioneer (vicinity) [8]	Venango	437-980				Numerous oil wells; large production.
Pithole City [9]	do	747				For oil or gas; unproductive.
Pittsburg	Allegheny	5,500				No water below 1,100.
Pittsburg (Lang avenue and Grazier street).[10]	do	4,700?				For oil or gas; abandoned.
Pittsburg (Twenty-first Ward).	do	1,616				Gas well.
Do	do	1,620				For oil or gas; abandoned.
Pittsburg (Twenty-fifth Ward).[11]	do	3,000	5⅝-5½			Large gas well.
Pittsburg (Twenty-fourth Ward).[12]	do	1,826				Gas well.
Pittsburg (Fourteenth Ward).[13]	do	2,007	5⅝			Dry hole.
Pittsburg (near steel works).[14]	do	2,360				For oil or gas.
Pittsburg (just outside of city).	do	1,901				Gas well.
Do	do	1,600				Small flow of gas.
Pittsburg (Thirty-fourth Ward).[15]	do	2,014	5⅝			For gas; unsuccessful, owing to salt water.
Pittsburg (Twenty-first Ward).[16]	do	1,635				
Pittsburg (Twenty-third Ward).	do	1,600				For gas; flooded with salt water.
Pittsburg (Thirty-third Ward).[17]	do	1,577				For oil or gas; abandoned on account of salt water.
Pittsburg (Fifteenth Ward).[18]	do	1,576				For oil or gas; abandoned.
Pittsburg (Twenty-first Ward).	do	1,575				For gas; flooded with water.
Pittsburg (Twenty-sixth Ward)	do	1,535				For oil or gas; abandoned on account of salt water.

[1] Records, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 148-149.
[2] Ibid., pp. 149-150.
[3] Ibid., p. 184.
[4] Ibid., Vol. I[4], p. 64.
[5] Ibid., pp. 16-18.
[6] Ibid., Vol. I[5], pp. 243-244.
[7] Ibid., Vol. III, pp. 409-410; Vol. II, p. 277.
[8] Ibid., Vol. II, pp. 43-64; Am. Phils. Soc., Proc., vol. 16, pp. 468-471.
[9] Records, Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 179.
[10] Ibid., pp. 276-277.
[11] Ibid., Ann. Rept., 1886, part 2, pp. 730-732.
[12] Ibid., pp. 733-736.
[13] Ibid., pp. 736-737.
[14] Record, Pa. 2d Geol. Surv., Reports, Vol. III, pp. 398-400.
[15] Ibid., Ann. Rept. for 1886, part 2, pp. 739-741.
[16] Ibid., Vol. I[5], pp. 275-276.
[17] Ibid., Ann. Rept. for 1886, part 2, p. 738.
[18] Ibid., p. 741.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Pittsfield (Township.)[1]	Warren	747				For oil or gas; unproductive.
Do.[2]	do	1,500				For oil or gas; unsuccessful.
Pittston	Luzerne	464–511	2			Two wells.
Pleasantville (2½ miles northwest)[3]	Venango	415				Oil well.
Pleasantville (4½ miles southeast).[4]	do	1,000				Gas and oil well.
Pleasantville (2 miles northeast).[5]	do	885				Do.
Pleasantville Borough.[6]	do	693–1,044				Numerous oil and gas wells.
Pleasant Towhship[7]	Warren	1,586				For oil or gas; unproductive.
Do.[8]	do	818–900				Several small oil wells.
Pleasant Unity (2½ miles northwest).[9]	Westmoreland.	650				For oil or gas; unproductive.
Plumer (1 mile south).[10]	Venango	464				
President (near)[11]	do	1,280				For oil or gas; abandoned.
Punxutawney (vicinity).[12]	Indiana	2,745				Gas well.
Radnor Station	Delaware	500	12			Abandoned.
Do	do	975	12–8	40–50	Pumped.	Probably surface water.
Randolph (vicinity)[13]	Crawford	565–950				Several oil wells.
Raymilton[14]	Venango	893–1,410				Numerous oil or gas wells.
Raymilton (near)[15]	do	845–1,410				Several oil or gas wells.
Reagantown (south of).[16]	Westmoreland.	2,070				For oil or gas; unproductive.
Reeds Corners[17]	Crawford	500				For oil or gas: abandoned.
Reibold[18]	Butler	1,707–1,711				Two oil wells.
Reno[19]	Venango	570–590				Several oil wells.
Do	do	1,090				For oil; unproductive.
Renovo	Clinton	4,000			−600	For oil; unsuccessful.
Do	do	3,460				Gas well.
Do	do	450–1,350				For oil or gas.
Richland Township[20]	Clarion	1,040–1,700				Several oil wells.
Richmond Township	Crawford	900				Oil and gas well.
Ridgway[21]	Elk	1,820				Small gas well.
Do.[22]	do	772				
Ridgway Township[23]	do	1,678				For oil; unsuccesful.
Riverton	Cumberland (?)	485	5			
Robinson Township[24]	Allegheny	1,770–2,427				Two oil and gas wells.
Rochester[25]	Beaver	965				For gas and oil.
Rockland Station[26]	Venango	701				For oil; abandoned.
Rockland Township[27]	do	600–1,100				Numerous oil wells.
Ross Township[28]	Allegheny	1,915–2,037				Two gas wells.
Rouseville (vicinity).[29]	Venango	450–800				Numerous oil wells.
Ryerson Station (north of).[30]	Greene	2,716				For oil or gas.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. II, p. 196.
[2] Ibid., p. 197.
[3] Ibid., Vol. I[5], p. 175.
[4] Ibid., Am. Philos. Soc., Proc., Vol. 16. p. 497.
[5] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 54–55.
[6] Ibid., Vol. II, pp. 9–34; Vol. III, p. 420; Vol. I[4], p. 55; Am. Philos. Soc., Proc., vol. 16, pp. 435–460.
[7] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 174.
[8] Ibid., Vol. I[4], p. 19.
[9] Ibid., Vol. II, pp. 280–281.
[10] Ibid., Vol. I[5], p. 180.
[11] Ibid., pp. 180–181.
[12] Ibid., Ann. Rept. for 1886, part 2, pp. 776–777.
[13] Pa. 2d Geol. Surv., Reports, Vol. Q[4], pp. 178–179.
[14] Record, ibid., Vol. I[5], pp. 181–183; Vol. I[4], p. 68; Vol. III, pp. 419–420.
[15] Ibid., Vol. I[4], pp. 68–69.
[16] Ibid., Vol. I[5], pp. 227–228.
[17] Ibid., Vol. Q[4], p. 212.
[18] Ibid., Vol. I[5], pp. 194–195.
[19] Ibid., Vol. II, pp. 208–210.
[20] Record, Pa. 2d Geol. Surv., Reports, Vol. II, pp. 226–227.
[21] Ibid., Ann. Rept. for 1886, Part II, p. 711.
[22] Ibid., Vol. G[4], pp. 142–143.
[23] Ibid., pp. 129–131.
[24] Ibid., Vol. I[5], pp. 268–269.
[25] Ibid., Vol. II, pp. 279–280.
[26] Ibid., Vol. II, p. 207.
[27] Ibid., pp 215–218.
[28] Ibid., Vol. I[5], pp. 255–257.
[29] Ibid., Amer. Phil. Soc., Proc., vol. 16, pp. 477–486.
[30] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 312–313.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
St. Joe (vicinity)[1]	Butler	1,445-1,577				Gas wells.
St. Marys (west of)[2]	Elk	2,010				Gas well.
Salem (vicinity)[3]	Venango	962-1,200				Several oil or gas wells.
Salem Township[4]	Clarion	1,198-1,200				Oil and gas wells.
Salisbury Basin[5]	Somerset	678				
Saltsburg (near)[6]	Indiana	2,014				For oil or gas; unproductive.
Sandy Creek Township.[7]	Venango	792				Small oil well.
Sarvers Station[8]	Butler	3,055				For oil or gas; abandoned.
Do[9]	do	1,930				
Saxon Station[10]	do	1,857				Gas well.
Saxonburg (2 miles west).[11]	do	1,825				For oil or gas.
Scranton (1 mile southeast).	Lackawanna	2,050	6			Abandoned.
Scranton (2 miles northwest).	do	+700	6	30	Flows.	
Scranton (3 miles west).	do	±1,000	6	40		
Scranton (6 miles northeast).	do	2,200	8-6			
Sergeant Station[12]	McKean	2,000				For oil or gas; abandoned.
Sergeant Station (near).[13]	do	2,263				Dry hole.
Do.[14]	do	2,000				
Sergeant Township[15]	do	2,004				For oil or gas.
Do.[16]	do	1,850				For oil and gas.
Do.[17]	do	1,785				For oil or gas; abandoned.
Do.[18]	do	2,043				Excellent gas well.
Do.[19]	do	1,802				Good gas well.
Do.[20]	do	2,000-2,380				Several oil and gas wells.
Sewickley Township.[21]	Allegheny	2,008-2,133				Gas and oil wells.
Shaler Township[22]	Allegheny	1,393				For gas; abandoned.
Shamburg[23]	Venango	547-972				Numerous oil wells.
Sharon (1½ miles above).[24]	Mercer	1,600				For gas or oil.
Sharpsburg (near)[25]	Allegheny	2,010				For oil or gas; abandoned.
Sheffield (vicinity)[26]	Warren	1,645				Good gas well.
Do[27]	do	1,565 (?)				For oil or gas; unsuccessful.
Do	do	825				For oil or gas; abandoned.
Do[28]	do	961-1,200				For oil or gas.
Sheffield Township[29]	do	1,435-2,016				Numerous oil and gas wells.
Shenandoah (near)	Schuylkill	538	8			Oil well.
Shippensville (1½ miles south).[30]	Clarion	2,025				For oil or gas; unproductive.
Sligo[31]	do	1,151				Oil well.
Slippery Rock Township.[32]	Butler	1,411				For oil or gas.
Do[33]	do	1,400-1,436				For oil; unproductive.

[1] Record, Pa. Geol. Surv., Ann. Rept. for 1886, Part II, pp. 713-714; Vol. I[4], p. 138.
[2] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 131-132.
[3] Ibid., Vol. II, pp. 205-206.
[4] Ibid., pp. 227-229.
[5] Ibid., Vol. I[4], pp. 146-147.
[6] Ibid., Vol. I[5], pp. 167-168.
[7] Ibid., Vol. II, p. 201.
[8] Ibid., Vol. I[5], pp. 193-194.
[9] Ibid., p. 194.
[10] Ibid., Vol. II, p. 269.
[11] Ibid., p. 270.
[12] Analysis, Pa. 2d Geol. Surv., Reports, Vol. R, p. 92.
[13] Ibid., pp. 243-245.
[14] Ibid., pp. 245-248.
[15] Record, Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 106-108.
[16] Ibid., pp. 108-111.
[17] Ibid., pp. 104-106.
[18] Ibid., Pa. 2d Geol. Surv., Ann. Rept. for 1886, Part II, pp. 695-696.
[19] Ibid., p. 698.
[20] Ibid., pp. 696-698, Vol. I[4], p. 117.
[21] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 243.
[22] Record, Pa. 2d Geol. Surv., Ann. Rept. for 1886, Part II, pp. 752-753.
[23] Ibid., Vol. II, pp. 34-42. Amer. Philos. Soc., Proc., vol. 16, pp. 460-468.
[24] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[3], p. 419.
[25] Ibid., Vol. I[4], pp. 138-139.
[26] Ibid., pp. 23, 379-380.
[27] Ibid., pp. 24, 380-381.
[28] Ibid., Vol. II, pp. 194-195.
[29] Ibid., pp. 193-194; Vol. I[4], pp. 24-26, Vol. I[5], pp. 174-175; Ann. Rept. for 1886, Part II, pp. 698-700.
[30] Ibid., Vol. I[3], pp. 414-415.
[31] Ibid., Vol. G[4], pp. 149-150; Vol. II, pp. 234-235.
[32] Ibid., Vol. QQ, p. 154.
[33] Ibid., Vol. I[4], pp. 143-144, Vol. I[3], 417-418.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Smethport (west of).[1]	McKean	2,004				For oil; abandoned.
Smethport (vicinity).[2]	do	1,293-1,900				Several oil and gas wells; small production.
Smiths Ferry[3]	Beaver	500				For oil or gas; unproductive.
Snowden Township[4]	Allegheny	2,348				Gas well.
Snydersburg[5]	Clarion	1,207				Oil well.
Sodom (near)[6]	Allegheny	2,275-2,502				Several gas wells.
South Fayette Township.[7]	do	2,140				Oil well.
South Shenango Township.[8]	Crawford	1,065				Do.
South Strabane Township.[9]	Washington	2,410-2,503				Gas wells.
South Versailles Township.	Allegheny	1,550				Gas well.
Do[10]	do	1,510-1,624				For oil or gas; abandoned on account of salt water.
Southwest Township.[11]	Warren	500-1,550				Numerous oil and gas wells.
Sparta Township[12]	Crawford	465-1,507				Several oil and gas wells; some productive.
Spartansburg (2½ miles southeast).[13]	do	745				Gas well.
Spence Run[14]	Allegheny	1,990				For oil or gas.
Spring Township	Crawford	512				Gas well.
Spring Creek Township.[15]	Elk	880				For oil; unsuccessful.
Do.[16]	Warren	600-1,061				Several oil and gas wells; small production.
Springdale Station (near).	Allegheny					For gas; unsuccessful.
Springfield Township.	Erie	400				For oil; unsuccessful.
Stoneboro (near)[17]	Mercer	950				Oil well.
Stoneham (vicinity)[18]	Warren	1,025-1,600				Several oil and gas wells; mostly productive.
Sugar Run[19]	McKean	970				Oil well.
Sugar Creek Township.[20]	Venango	583-606				Two oil wells; one abandoned,
Sulphur Run[21]	do	925-1,350				Two oil wells.
Summit[22]	Butler	1,822				Gas well.
Summit Township[23]	do	1,735				Oil well.
Do	Erie	400				Gas well.
Tarentum	Allegheny	+1,160				For gas or oil; abandoned.
Tarentum (vicinity).[24]	do	482-1,705				Several gas and oil wells; small production.
Tarentum (3½ miles northeast).[25]	do	2,010				For oil or gas; unproductive.
Tarentum (1½ miles southeast).	Westmoreland.					For oil or gas; abandoned.
Taylorstown[26]	Washington	2,350-2,760				Several gas and oil wells.
Throop	Lackawanna	2,380				Water in small quantity.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. R, pp. 271-272.
[2] Ibid., pp. 272-276.
[3] Ibid., Vol. II, pp. 281-282.
[4] Ibid., Vol. I^3, pp. 273-274.
[5] Ibid., Vol. G^4, p. 149; Vol. I^4, p. 140.
[6] Ibid., Vol. I^5, pp. 269-273.
[7] Ibid., p. 273.
[8] Ibid., Vol. Q^4, p. 153.
[9] Ibid., Vol. I^5, p. 280.
[10] Ibid., Ann. Rept. for 1886, Part II, pp. 751-752.
[11] Record, Pa. 2d Geol. Surv., Reports, Vol. I^4, pp. 49-52; Vol. I^5, p. 855; Am. Phil. Soc., Trans., vol. 16, pp. 346-367.
[12] Ibid., Vol. I^5, pp. 186-187; Vol. Q^4, p. 227.
[13] Ibid., Vol. II, p. 69; Am. Philos. Soc., Proc., vol. 16, p. 493.
[14] Ibid., Pa. 2d Geol. Surv., Ann. Rept., 1886, part 2, p. 744.
[15] Ibid., Vol. I^4, pp. 132-133.
[16] Ibid., pp. 252-263.
[17] Ibid., p. 121.
[18] Ibid., pp. 20-23.
[19] Ibid., Vol. I^4, p. 91.
[20] Ibid., Vol. II, pp. 200-201.
[21] Ibid., Vol. I^5, pp. 182-183.
[22] Ibid., Vol. I^3, p. 404.
[23] Ibid., Vol. II, pp. 268-269.
[24] Ibid., Vol. I^3, pp. 405-408.
[25] Ibid., Vol. I^5, pp. 238-239.
[26] Ibid., pp. 298-299.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Tidioute (vicinity)[1]	Warren	403-715				Numerous oil and gas wells; none large producers, and many abandoned.
Tionesta (near)[2]	Forest	437				Oil and gas well.
Tionesta Township[3]	do	554-2,177				For oil or gas; unproductive.
Titusville	Crawford	600	10			
Titusville (near)[4]	do	3,553				For oil or gas.
Titusville (vicinity)[5]	do	400-806				Numerous oil and gas wells.
Do.[6]	Venango	538-966				Do.
Toby Township[7]	Clarion	1,400	8			Oil well.
Towet City	Schuylkill	418				
Tremont	do		8			Do.
Triumph[8]	Warren	+472				For oil; unsuccessful.
Triumph (vicinity)[9]	do	739-815				Several oil wells.
Triumph Township[10]	do	2,464-2,700				For oil or gas; unsuccessful.
Do.[11]	do	805-908				Numerous oil and gas wells.
Troy Township	Crawford	500-1,700				Several oil and gas wells; some unproductive.
Tryonville (vicinity)	do	600-1,000				Oil and gas wells.
Tuna Valley[12]	McKean	1,035-1,919				Several oil and gas wells.
Turkey City (near)[13]	Clarion	1,150				For oil or gas.
Union City[14]	Erie	1,523				For oil or gas; unsuccessful.
Union Township	do	1,600				For oil; unsuccessful.
Uniontown (3 miles northwest).[15]	Fayette	2,001				Gas well.
Upper Middletown[16]	do	2,440				For oil or gas; unproductive.
Upper St. Clair Township.[17]	Allegheny	2,442				Gas well.
Venice (1 mile northwest).[18]	Washington	2,247	7⅞-5⅝			For oil or gas; unsuccessful.
Wall Station (near)	Allegheny	1,850		Many.	Flows.	Water charged with soda; temp. 65°-70°; also gas well.
Waltz Mill (near)[19]	Westmoreland.	1,769-3,151				Two borings for oil or gas; unproductive.
Warren (near)[20]	Warren	531-1,065				Numerous oil and gas wells; some good producers.
Washington[21]	Washington	2,285-2,599				Several oil and gas wells.
Washington (near)[22]	do	1,977-2,420				Do.
Washington Township.[23]	Westmoreland.	1,301-1,638				Gas wells.
Waterford (2 miles west).	Erie	650				Oil and gas wells.
Watson Township[24]	Warren	1,936				For oil or gas; unproductive.
Wayne Township[25]	Lawrence	790				For oil; unsuccessful.
Do	Erie	600				Gas and oil well.
Do.[26]	Crawford	600-1,100				Several oil and gas wells.
Waynesburg[27]	Greene	2,745				Oil well; abandoned.

[1] Record, Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 31-48; Am. Phil. Soc., Proc., vol. 16, pp. 372-374.
[2] Record, Am. Philos. Soc., Proc., vol. 16, p. 488.
[3] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 77-79; Ann. Rept. for 1886, part 2, pp. 705-707.
[4] Ibid., Vol. Q[4], p. 184; Vol. I[3], p. 154; Vol. I[4], p. 284.
[5] Ibid., Am. Philos. Soc., Proc., vol. 16, pp. 490-493; Pa. 2d Geol. Surv., Reports, Vol. I[4], pp. 118-119.
[6] Ibid., Pa. 2d Geol. Surv., Reports, Vol. I[4], p. 56.
[7] Ibid., Vol. I[3], pp. 412-413.
[8] Record, Am. Philos. Soc., Proc., vol. 16, p. 494.
[9] Ibid., pp. 370-372.
[10] Records, Pa. 2d. Geol. Surv., Reports, Vol. I[4], pp. 280-283.
[11] Ibid., Vol. I[5], pp. 173-174; Vol. I[3], pp. 283-286.
[12] Ibid., Vol. I[4], pp. 87-92.
[13] Ibid., Vol. II, p. 227.
[14] Ibid., Vol. I[4], p. 121.
[15] Ibid., Vol. I[5], pp. 320-321.
[16] Ibid., p. 319.
[17] Ibid., pp. 271-272.
[18] Record, Pa. 2d Geol. Surv., Ann. Rept. for 1886, part 2, pp. 759-760.
[19] Ibid, Vol. I[5], pp. 225-227.
[20] Ibid., Vol I[4], pp. 1-9.
[21] Ibid., Ann. Rept. for 1886, part 2, pp. 764-767.
[22] Ibid., pp. 760-769.
[23] Ibid., pp. 726-730.
[24] Ibid., Vol. I[4], p. 20.
[25] Ibid., Vol. QQ, p. 89.
[26] Ibid., Vol. Q[4], pp. 122-125.
[27] Ibid., Ann. Rept. for 1886, part 2, pp. 772-773.

PENNSYLVANIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Waynesburg (vicinity).[1]	Greene	2,675–2,900				Two oil and gas wells; one unproductive.
Wellersburg	Somerset	1,207				Good water.
Wellsboro	Tioga					
West Alexander (3 miles west).[2]	Washington	3,200				For oil or gas; unproductive.
West Amity Station (near).[3]	do	+2,390				Gas well.
West Branch Township.[4]	Potter	1,750–2,750				For oil; unsuccessful.
West Deer Township.[5]	Allegheny	2,243				For oil or gas; unproductive.
West Middletown[6]	Washington	3,455				For oil or gas; abandoned.
Wicks Station[7]	Butler	912				
Wilcox (4½ miles north).[8]	Elk	1,850				Small oil well.
Wilkesbarre	Luzerne	536	2			
Do	do	466				For water; unsuccessful.
Willow Tree[9]	Greene	2,165				For oil or gas; abandoned.
Winfield Township[10]	Butler	1,685				For oil or gas; unsuccessful.
Woodcock Township	Crawford	+600				For oil: unsuccessful.
Woodrow (near)[11]	Washington	+4,303				Gas well.
Wrightsville (1 mile northeast).[12]	Warren	1,200				Abandoned as dry hole.

[1] Record, Pa. 2d Geol., Surv., Reports, Vol. I[5], p. 312.
[2] Ibid., pp. 304–315.
[3] Ibid., p. 307.
[4] Ibid., Ann. Rept. for 1885, pp. 86–91.
[5] Ibid., Vol. I[5], p. 241.
[6] Ibid., Ann. Rept. for 1886, part 2, pp. 756–758.
[7] Ibid., p. 720.
[8] Ibid., Vol. G[4], pp. 143–146.
[9] Ibid., Vol. I[5], p. 316.
[10] Ibid., Ann. Rept. for 1886, part 2, p. 716.
[11] Ibid., pp. 755–756.
[12] Ibid., Vol. I[4], p. 236.

PUBLICATIONS RELATING TO DEEP BORINGS IN PENNSYLVANIA.

Oil Well Records, selected from the collections of Mr. J. F. Carll, by J. P. Lesley, American Philosophical Society, Proceedings, vol. 16, pp. 346–380, Philadelphia, 1877.

On the First Systematic Collection and Discussion of the Venango County Oil Wells of Western Pennsylvania, by E. S. Nettleton, prepared for publication by J. F. Carll, American Philosophical Society Proceedings, Nos. 97–99, for 1876–1877, vol. 16, pp. 429–495, Philadelphia, 1877.

Pennsylvania Second Geological Survey, Report of Progress, 1876–1877, Oil Well Records and Levels, by J. F. Carll, Vol. II, 398 pages, Harrisburg, 1877.

Pennsylvania Second Geological Survey, Report for 1875–1879, The Geology of the Oil Regions of Warren, Venango, Clarion, and Butler Counties, by J. F. Carll, Vol. III, 482 pages, Harrisburg, 1880.

Pennsylvania Second Geological Survey, Report of Progress, 1879, The Geology of Erie and Crawford Counties, by I. C. White, Vol. QQQQ, 406 pages, Harrisburg, 1881.

Pennsylvania Second Geological Survey, Report for 1880–1883, Geological Report on Warren County and Neighboring Oil Regions, by J. F. Carll, Vol. I[4], 439 pages, Harrisburg, 1883.

Pennsylvania Second Geological Survey, Annual Report, 1886. part 2, Report on the Oil and Gas Regions, by J. F. Carll, pp. 575–918, Harrisburg, 1887.

Pennsylvania Second Geological Survey, Seventh Report on the Oil and Gas Fields of Western Pennsylvania for 1887–1888, by J. F. Carll, Vol. I[5], 356 pages, Harrisburg, 1890.

RHODE ISLAND.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Providence	Providence	400	6	85	No flow.	
Do	do	460	6	110	No flow.	
Saylesville	do	1,436		15	No flow.	Abandoned.

SOUTH CAROLINA.

Abbeville	Abbeville	504	8	80	—3	
Aiken[1]	Aiken	558	8–6	50	—170	In granite.
Bamberg[2]	Barnwell	479–555	1¼–2	35–40	+12–30	Several wells.
Beaufort[3]	Beaufort	800				
Camden	Kershaw	618–625		Many.	—20	Two wells.
Charleston[4]	Charleston	1,970		250	+4	Temp. 99.5°.
Do.[5]	do	1,260		30	+25	Saline water; temp. 87°.
Do	do	1,950	3¼	167		Temp. 99°.
Do	do	1,970	2 11/16	104		Do.
Do	do	2,050	4	451		Do.
Do	do	1,945	5	695		Do.
Charleston (vicinity)[6]	do	425–475				Several wells.
Chester	Chester	700				In granite; unsuccessful.
Do	do	500	8			Unsuccessful.
Florence[7]	Florence	1,335	10–8	100	—20	Lowest water at 1,215 to 1,220.
Do	do	420		Many.		Fine water.
Georgetown	Georgetown	400?		Not any		
Green Pond	Colleton	503	3	1	Flows.	Temp. 70°.
Greenwood	Abbeville	400	8	40	—4	
Hampton	Hampton	800			Flows.	
Do	do	583	6	Many.	—9	Soft, irony water.
Jacksonboro	Colleton	420	3	4	Flows.	Temp. 72°.
Johns Island		500	6	11	Flows.	Temp. 70°.
Marion	Marion	1,244	8–6	½	Flows.	
Mays River Neck		800			—1	Very sulphurous water.
Orangeburg[8]	Orangeburg	1,160	6–2¾	Many.	—52	Pumped at 300 feet.
Peeples	Hampton	850	6	100	Flows.	Temp. 76°.
Sullivans Island	Laurens	1,308	12–3	10		Temp. 87°.
Varnville	Hampton	983	6	Many.	—12	
Walterboro	Colleton	490	6	Many.	—30	Soft water.

[1] Record, U. S. Geol. Surv., Bull. No. 138, p. 220.
[2] Ibid., p. 221.
[3] Analysis, Ibid., p. 217.
[4] Record, Municipal Report of City of Charleston, 1881, Artesian Wells, Report of Scientific Committee, pp. 3–4, plate.
[5] Analysis, U. S. Geol. Surv., Bull. No. 138, p. 212.
[6] Ibid., pp. 214–216.
[7] Record and Analysis, Ibid., pp. 218–219.
[8] Record, Ibid., p. 220.

PUBLICATIONS RELATING TO DEEP BORINGS IN SOUTH CAROLINA.

Municipal Report of the City of Charleston, S. C., 1881; Artesian wells, report of Scientific Committee, etc., 61 pages, plates, Charleston, 1882.

Artesian Well prospects in the Atlantic Costal Plain region, by N. H. Barton, U. S. Geological Survey, Bulletin No. 138, 232 pages, plates, Washington, 1896.

SOUTH DAKOTA.

[Arranged by counties.]

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Plankinton Township.	Aurora	775	4½	200	+127	
Plankinton	do	830	4½-3	225	+209	Flows at 540 and 740 feet also.
Do	do	745	4	60		
White Lake	do	863	4	150	+80	Flows at 790 and 850 feet.
Crystal Lake Township, sec. 17.	do	850	4½	600	+127	
T. 105, R. 63, sec. —	do	475	2	5		
T. 105, R. 66, sec. 24	do	953	2	115		
T. 104, R. 63, sec. 22 [1]	do	525	4-3	168		
T. 104, R. 66, sec. 2	do	844	2	150		A flow also at 710 feet.
T. 104, R. 63, sec. 21	do	523	4½	150	+103	
Do	do	525	4½	150		
T. 104, R. 63, sec. 1	do	470	2	4		
T. 104, R. 66, sec. 3	do	922	2	75		
T. 103, R. 63, sec. 26 [1]	do	490	4	10		
Do	do	530	2	10		
T. 103, R. 63, sec. 35	do	484	4-3			
T. 103, R. 63, sec. 32	do	623	3-2	15		A flow also at 520 feet.
T. 103, R. 66, sec. 34	do	842	6			Flows at 650 and 842 feet.
T. 103, R. 63, sec. —	do	705	3	200		
T. 103, R. 63, sec. 28	do	716				Flows at 600 and 675 feet.
T. 103, R. 63, sec. —	do	530	2	30		
T. 103, R. 63, sec. 13	do	420	2	30		
T. 102, R. 66, sec. 17	do	835	4	400		
T. 102, R. 63, sec. 10 [1]	do	613	2	3		
Hitchcock [2]	Beadle	953	4-3	1,260	+345	
Huron [2]	do	906	6	1,500	+276	Flows at 712 and 772 feet also.
Do	do	847	6-4	600	+276	Flows at 776 and 826 feet.
Do	do	1,040	8	350		A flow at 756 feet also.
Huron (1 mile sw.)	do	1,080	5½	1,500		A flow at 900 feet also.
Huron [2]	do	960	10-5⅝	2,250	+380	Temp. 70°. Several flows 240 to 960 feet.
Wolsey [2]	do	930	8-5	330		Flows at 490, 808, 858, and 893 feet also.
T. 113, R. 64, sec. 15	do	1,066	4	600	Flows.	
T. 113, R. 64, sec. 29	do	1,118	4	1,435	+403	
T. 112, R. 61, sec. 30 [3]	do	917	6-4		Flows.	Flows at 770 and 800 feet also.
T. 111, R. 61, sec. 19	do	836	3	360	+338	
T. 111, R. 61, sec. 31	do	792	3	200	+292	
T. 110, R. 62, sec. 11	do	1,080	5½	1,500	Flows.	Flow at 900 feet also.
T. 110, R. 60, sec. 29	do	930	4	930	+230	
T. 109, R. 62, sec. 30	do	813	3	250	+288	
Scotland	Bonhomme	590	6			
Do [4]	do	587		9		
Springfield [4]	do	592	8	3,292	+198	
Do	do		4			
Tyndall [4]	do	736	4½	1,000	+69	
Do	do	752	8			
Choteau Creek	do	862?		1,400	+143	
Do	do	897	6	1,600	+133	
T. 96, R. 59, sec. 15 [5]	do	700	2			
Do. [5]	do	590	7	1	+126	
Do. [5]	do	645	3		+149	
T. 94, R. 61, sec. 22 [4]	do	1,074⅝	3-2½	½	+6	
T. 94, R. 60, sec. 9	do	768	2	60		
T. 94, R. 58, sec. 32	do	640	2	75		
T. 93, R. 59, sec. 1	do	646	1	30	+143	
T. 93, R. 58, sec. 5 [6]	do	660	3	95	+104	
T. 95, R. 59, sec. 34	do	730	2	97	+82	
T. 60, R. 93, sec. 5 [7]	do	825				
T. 94, R. 58, sec. 19	do	576	3	11		
Aberdeen [8]	Brown	955	8-3	Many.	+230	Flows at 925 and 940 feet.

[1] Record, U. S. Geol. Surv., 18th Ann. Rpt., part 4, Pl. XL.
[2] U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 22-23.
[3] Ibid., Pl. 76.
[4] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, p. 58.
[5] At Hutterisches Colony, Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 587.
[6] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, p. 50.
[7] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 586.
[8] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pl. 72.

SOUTH DAKOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Aberdeen [1]	Brown	1,050	6–5	1,060	+317	
Do. [1]	do	918	$3\frac{3}{16}$	330	+92	Flows at 879 and 905 feet.
Do. [1]	do	1,004	6–4	825	+143	
Do. [1]	do	1,066	8–2	Many.	Flows.	Flows at 910, 921, and 1,020 feet also.
Do. [1]	do	1,300	8–$4\frac{1}{2}$	1,080	+196	Flows at 920, 995, and 1,077 feet.
Aberdeen, T. 123, R. 63, sec. 17.	do	1,117	$4\frac{1}{2}$	Many.	Flows.	Flows at 925 and 1,090 feet.
Aberdeen. T. 123, R. 63, sec. 18.	do	1,015	$4\frac{1}{2}$	300	+288	Flows also at 928 feet.
Columbia [1]	do	964	$4\frac{1}{2}$	940	+368	Five flows 721–927 feet.
Frederick [1]	do	1,139	6–4	139	+161	Flows at 985 and 1,045 feet also.
Groton [1]	do	960	$5\frac{3}{16}$–$3\frac{3}{4}$			
Do	do	922	6–3	830	+310	
T. 127, R. 63, sec. 12 [2]	do	856			Flows.	
T. 127, R. 63, sec. 21 [2]	do	800			Flows.	
T. 126, R. 60, sec. 32	do	1,030	6		+80	
T. 126, R. 61, sec. 31 [2]	do	965			Flows.	
T. 125, R. 61, sec. 3 [2]	do	716			Flows.	
T. 124, R. 60, sec. 31 [2]	do	942	4–2	150	+315	
T. 123, R. 60, sec. 8 [2]	do	977		105	+184	
Chamberlain [3]	Brule	600	8		+219	
Do. [3]	do	685	10–8	4,350	+253	
Do	do	1,026	6	3,000	Flows.	
Do	do	815		300	Flows.	Flows at 716, 750, and 780 feet also.
Do	do	563	2		Flows.	
Do	do	600	2	2	Flows.	
Kimball [3]	do	1,068	$4\frac{1}{2}$	185	+46	
T. 105, R. 68, sec. 26 [3]	do	935	6	815	+173	Flows at 750, 825, and 875 feet also.
T. 105, R. 68, sec. 3	do	987	6		Flows.	
T. 104, R. 70, sec. 33	do	900	6		Flows.	
T. 103, R. 71, sec. 12	do	1,030	6	700	Flows.	
T. 103, R. 68, sec. 1	do	1,065	6	750	+46	
T. 103, R. 68, sec. 27	do	980	8		Flows.	
T. 102, R. 70, sec. 21	do	1,185	6	800	Flows.	
T. 102, R. 67, sec. 18	do	1,050	6	1,000	Flows.	
T. 102, R. 68, sec. 16	do		6		Flows.	
T. 102, R. 70, sec. 9	do	1,165		Many.	Flows.	
T. 102, R. 70, sec. 15	do	1,100	6	800	Flows.	
T. 102, R. 70, sec. 2	do	1,027		Many.	Flows.	
T. 102, R. 71, sec. 2	do	1,227	8	600	Flows.	
T. 102, R. 71, sec. 2	do	1,230	8	900	Flows.	
T. 101, R. 68, sec. 12	do	937	6	1,098	Flows.	Flows at 753, 786, and 851 feet also.
T. 101, R. 68, sec. 21	do	962	8–4	Many.	Flows.	
Crow Creek Agency [4]	Buffalo	780	6		+414	Temp. 72°; flows at 409 feet also.
Belle Fourche	Butte	525	8	60	+70	Two wells; another flows at 410 feet.
Chandler	Charles Mix	900	2			Uncompleted.
Greenwood [5]	do	651	6	3,000	+274	Temp. 70°; several flows 420–641 feet.
Lake Andes [5]	do	755½	8–6	1,500	+161	Temp. 70°; flows at 623 and 725 feet also.
Do. [5]	do	802	8–6	1,500	+161	Temp. 70°.
T. 100, R. 69, sec. 9	do	980	3	125	Flows.	Chalk at 210 feet.
T. 100, R. 71, sec. 29	do	785	8	500	Flows.	
T. 100, R. 71, sec. 18	do	868	8	2,352	Flows.	
T. 100, R. 68, sec. 13	do	720	2–1	Several.	Flows.	
T. 100, R. 68, sec. 9	do	830	2–$1\frac{1}{2}$	7	Flows.	
T. 99, R. 69, sec. 19	do	966	2–$1\frac{1}{2}$	60	+115	Flows at 779, 803, 838, and 860 feet also.
T. 100, R. 71, sec. 26	do	688	8	1,700	Flows.	Flows at 500 and 614 feet also.
T. 99, R. 67, sec. 18	do	769	2–1	7	Flows.	Water at 515 feet.
T. 99, R. 67, sec. 21 [6]	do	907	8–$4\frac{1}{2}$	40	Flows.	
T. 98, R. 68, sec. 13	do	1,006	6–4		No flow.	
T. 98, R. 64, sec. 20	do	772	2	200	+120	

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 16–18, pl. 72.
[2] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 15–17.
[3] Ibid., pp. 42–48.
[4] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 573.
[5] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 570.
[6] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 44–45.

SOUTH DAKOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Clark	Clark	1,200				Two wells; unsuccessful.
T. 117, R. 59, sec. 22 [1]	do	1,200	6			
T. 95, R. 52, sec. 9	Clay	500	3-2	3	Flows.	
T. 94, R. 52, sec. 11	do	402	2	5	Flows.	
T. 94, R. 52, sec. 15	do	400	1¼	Many.	Flows.	
T. 94, R. 53, sec. 33	do	500	2	Few.	Flows.	
T. 93, R. 51, sec. 29	do	400	1½	3	Flows.	
T. 93, R. 51, sec. 31	do	410	1	1	Flows.	
T. 92, R. 51, sec. 33	do	400	3-2	Few.	Flows.	
Vermilion	do	507	3	Few.	Flows.	
Buffalo Gap	Custer	800				Two borings; no water.
Mitchell [2]	Davison	548			+16	
Do	do	586	8	600	+64	Flows at 285, 445, and 560 feet.
Mitchell (12 miles southwest). [2]	do	433	2	20	Flows.	
Mitchell (6 miles northeast). [2]	do	472	2	40	Flows.	
Mitchell	do	550	2	60	+30	
Mount Vernon	do	442	2	8	Flows.	
Mount Vernon (14 miles southeast).	do	515	4½-3½	50	Flows.	
T. 104, R. 60, sec. 17 [2]	do	400		100	Flows.	
T. 104, R. 62, sec. 9 [3]	do	550	2-1	130	Flows.	
T. 104, R. 60, sec. 17 [3]	do	456	3	10	Flows.	
T. 103, R. 62, sec. 4	do	495	4	30	Flows.	
T. 103, R. 62, sec. 3 [3]	do	646	4½	700	Flows.	
T. 104, R. 61, sec. —	do	415		30	Flows.	
T. 104, R. 61, sec. 12	do	410	2	40	Flows.	
T. 104, R. 62, sec. 18	do	408	2	20	Flows.	
T. 104, R. 62, sec. 21	do	424	3	156?	Flows.	
T. 104, R. 62, sec. 12	do	416	2	5	Flows.	
T. 104, R. 62, sec. 3	do	601	4-3	130	Flows.	
T. 104, R. 62, sec. 7	do	444	2	15	Flows.	
T. 104, R. 62, sec. 35	do	479	5-4	Many.	Flows.	
T. 104, R. 60, sec. 35	do	507	4½-3	40	Flows.	
T. 104, R. 62, sec. 6	do	458	1	3	Flows.	
T. 104, R. 61, sec. 29	do	419	2	50	Flows.	
T. 104, R. 61, sec. 8	do	577	2	50	Flows.	
T. 104, R. 61, sec. 18	do	653	2-1	90	Flows.	
T. 104, R. 61, sec. 33	do	425	3	210	Flows.	
T. 104, R. 61, sec. 20	do	420	2	22	Flows.	
T. 103, R. 61, sec. 19	do	411	2	120	Flows.	
T. 103, R. 62, sec. 2	do	420	2	60	Flows.	
T. 103, R. 62, sec. 14	do	450	2	60	Flows.	
T. 103, R. 62, sec. 10	do	495	3	35	Flows.	
T. 103, R. 62, sec. 11	do	408	2	45	Flows.	
T. 103, R. 62, sec. 15	do	406	2	60	Flows.	
T. 103, R. 61, sec. 19	do	410	2	110	Flows.	
T. 102, R. 62, sec. 9	do	460	2	90	Flows.	
T. 102, R. 62, sec. 31	do	642	2-1¼	20	Flows.	
T. 102, R. 62, sec. 29	do	485	2-1¼	30	Flows.	
T. 102, R. 62, sec. 6	do	460	2	25	Flows.	
T. 101, R. 61, sec. 25	do	520	2	27	Flows.	
T. 101, R. 61, sec. 28	do	530	2	15	Flows.	
T. 101, R. 61, sec. 21	do	535	1¼	35	Flows.	
T. 101, R. 61, sec. 2	do	425	2	30	Flows.	
T. 101, R. 60, sec. 32	do	435	2	25	Flows.	
T. 101, R. 60, sec. 9	do	477	2		Flows.	
T. 101, R. 60, sec. 29	do	413	2	35	Flows.	
S. S. Slade's well	do	440	2	10	Flows.	
Andover [4]	Day	1,075	6-4½	300	+207	
Webster	do	1,400				Small flow only at 1,100 feet.
Cheyenne Agency [5]	Dewey	1,337	4	500	+472	Temperature 80°.
Armour	Douglas	800	8	1,500	Flows.	
Do. [6]	do	737	6	1,500	+126	
Delmont [6]	do	821	2	60	Flows.	
Flensburg [6]	do	611	2	60	Flows.	
Do	do	651	2		Flows.	
Do	do	775	2	65-70	Flows.	
T. 100, R. 64, sec. 26 [6]	do	937	6	900	+72	

[1] Record, U. S. Geol. Surv., 18th Ann. Rept., 1897, part 4, pp. 18, 21.
[2] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 39-40, 44.
[3] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 575.
[4] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, p. 19.
[5] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 588.
[6] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 46-50.

SOUTH DAKOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
T. 100, R. 64, sec. 26	Douglas	975	4	1,000	Flows.	
T. 100, R. 62, sec. 18	do	1,025		1,025	Flows.	
T. 100, R. 63, sec. 15	do	750	4	600-700	Flows.	
T. 100, R. 62, sec. 16	do	600	2	Many.	Flows.	
T. 98, R. 65, sec. 2 [1]	do	860	6	900	Flows.	
T. 99, R. 63, sec. 35	do	703½	8-6	2,100	+172	
T. 99, R. 65, sec. 14	do	925	4	600-700	Flows.	
T. 99, R. 65, sec. —	do	1,010	6	1,000	Flows.	
T. 98, R. 65, sec. 2	do	901	8-6	650	Flows.	
Ipswich	Edmunds	1,265	4½-3¾	Many.	+244	
Ardmore	Fall River	1,500				Unsuccessful.
Argentine [2]	do	550			Flows.	
Edgemont [3]	do	1,125		Several.	— 60	Plugged at 700 feet; water from 500 feet.
Edgemont (near)	do	960		Several.	— 30	Water from 578 feet.
Minnekahta [4]	do	1,348		None.		
Faulkton	Faulk	1,032		100	Flows.	
Orient (4 miles NE.) [5]	do	1,215	6-5¼	950	Flows.	
T. 113, R. 69, sec. —	Hand	1,200			Flows.	Flows at 1,087 and 1,127 feet also.
T. 113, R. 67, sec. 25	do	1,137	6-3	480	Flows.	
T. 112, R. 68, sec. 7	do	1,200	4	50	Flows.	
St. Lawrence	do	1,272		Few.	+ 92	First flow at 1,070 feet.
Miller [6]	do	1,139	6¼-4½	360	+276	
T. 112, R. 68, sec. 10	do	1,140	3½		Flows.	
T. 112, R. 67, sec. 33	do	1,375	3	1,000	+273	
T. 112, R. 67, sec. 18	do	1,343	3	350	+287	
T. 104, R. 57, sec. 8 [7]	Hanson	589	2-1¼	50	Flows.	
T. 104, R. 58, sec. 14 [7]	do	528	2-1¼	30	Flows.	
T. 104, R. 58, sec. 13 [7]	do	550	2	150	Flows.	
T. 104, R. 57, sec. 22	do	543	2	50	Flows.	
T. 104, R. 58, sec. 9	do	535	2	5	Flows.	
T. 104, R. 58, sec. 17	do	440	1	Few.	Flows.	
T. 104, R. 57, sec. 8	do	600	1¼	20	Flows.	
T. 104, R. 58, sec. 12 [8]	do	483	4	35	+46	
T. 104, R. 57, sec. 27	do	508	2	4	Flows.	
T. 104, R. 57, sec. 7	do	510	3-2	16	Flows	
East Pierre [9]	Hughes	1,192		900	+380	
Harrold [9]	do	1,453	4	84	+62	Temp. 95°.
Pierre	do	1,160		600	Flows.	Temp. 92°.
Menno	Hutchinson	417	6			Small flow.
Northwest corner of county. [10]	do	560		10		
Parkson [10]	do	542	3	30	+46	
Parkson (1 mile southwest). [10]	do	515		50	Flows.	
Tripp (4 miles north) [10]	do	580-540	2	9	Flow.	Three wells.
Tripp	do	815	6	700	+21	
T. 97, R. 57, sec. 21	do	747	2	6	Flows.	
T. 98, R. 61, sec. —	do	482		60	Flows.	
T. 98, R. 60, sec. 21	do	559	2	50	Flows.	
T. 99, R. 60, sec. 7	do	527	2	150	Flows.	
T. 100, R. 61	do	419-585	3-1¼	90-1	Flow.	Fourteen wells.
T. 100, R. 60	do	420-462	2	10-3	Flow.	Three wells.
T. 100, R. 61, sec. 25 [11]	do	458	2		Flows.	
T. 99, R. 61	do	490-572	2-1¼	50-8	Flow.	Fourteen wells.
T. 99, R. 60 [11]	do	485	2	25	Flows.	
T. 99, R. 60 [11]	do	485	1¼	90	Flows.	
T. 99, R. 60	do	400-540	6-1¼	25-1	Flow.	Twelve wells.
T. 98, R. 60 [11]	do	559	2	50	Flows.	
T. 98, R. 59	do	400-450	2-1¼	15-1	Flows.	Six wells.
T. 99, R. 59	do	490	2		Flows.	
T. 98, R. 60	do	475-580	5-2	120-10	Flow.	Fifteen wells.
T. 98, R. 61	do	500-798	3-1¼	40-13	Flow.	Nine wells.
T. 97, R. 60	do	550-614	4½-1½	50-40	Flow.	Three wells, not including town well at Tripp.
T. 97, R. 61	do	945			Flows.	
T. 97, R. 59	do	517-550	2 1¼	30	Flow.	Two wells.

[1] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pp. 46-50.
[2] Analysis, U. S. Geol. Surv., 21st Ann. Rept., 1899-1900, part 4, p. 570.
[3] Ibid., pp. 568, 571.
[4] Ibid., p. 573.
[5] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, p. 22.
[6] Ibid., p. 26.
[7] Ibid., pl. 84.
[8] Record, U. S. Geol. Surv., 18th Ann. Rept., part 4, p. 579.
[9] Record, U. S. Geol. Surv., 17th Ann. Rept., part 2, pl. 76.
[10] Ibid., pp. 47-48.
[11] Record, U. S. Geol. Surv., 18th Ann. Rept., 1897, part 4, pp. 580-585.

SOUTH DAKOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
T. 97, R. 57, sec	Hutchinson	500-406	2-1¼	2	Flow.	Two wells.
T. 97, R. 57	do	747-485	2-1¼	4-3	Flow.	Do.
T. 97, R. 56	do	445	2		Flows.	
Highmore [1]	Hyde	1,552	6	9	+ 35	Temp. 72°.
T. 108, R. 64, sec. 11	Jerauld	799	2-1¼	2	Flows.	
T. 108, R. 65, sec. 5 [2]	do	1,057	2½	200	+207	
T. 106, R. 63, sec. 2	do	715	2	200	+304	
T. 106, R. 63, sec. 6	do	760	3-2	280	+253	
T. 106, R. 64, sec. 9 [2]	do	880	2½	280	+262	
T. 106, R. 64, sec. 17	do	810	2½	5	Flows.	
T. 106, R. 64, sec. 15	do	816	3	10	Flows.	
Desmet	Kingsbury	1,610				
Arlington	do	800			No flow.	
Iroquois [3]	do	1,115	4½	1,000	+154	
T. 109, R. 58, sec. 30	do	600	2		Flows.	
Britton [4]	Marshall	1,004	8-3½	600	+365	Temp. 64°.
Langford	do	1,050	6	400-500	+138	
Newark	do	940	8-6	600	+288	Water at 420, 480, and 900 feet.
Rosebud Agency (26 miles northeast).	Meyer	2,500	8-6		−600	
Gettysburg	Potter	2,140			−100	
Artesian (1 mile southwest). [5]	Sanborn	±630	3		+ 81	
Letcher [6]	do	577	3-2	90	+207	Water at 300, 400, and 570 feet.
T. 105, R. 61, sec. 23 [6]	do	561		125	Flows.	
T. 105, R. 61, sec. 15 [6]	do	578	2	70	Flows.	
T. 107, R. 62, sec. 29	do	742	3	425	+299	
T. 105, R. 62, sec. 26	do	445	2-1	3	Flows.	
T. 105, R. 60, sec. 10	do	625	2	30	Flows.	
T. 105, R. 60, sec. 20	do	497	2	165	Flows.	
T. 105, R. 62, sec. 19	do	485	2	4	Flows.	
T. 105, R. 62, sec. 17	do	463	2	6	Flows.	
T. 105, R. 62, sec. 30	do	500	1½	15	Flows.	
T. 105, R. 60, sec. 14	do	511	2	100	Flows.	
T. 105, R. 61, sec. 15	do	584	2	80	Flows.	
T. 105, R. 60, sec. 27	do	445	2	30	Flows.	
Woonsocket [6]	do	725	6	1,150	+299	
Do	do	775		Many.	+288	
Ashton	Spink	1,003	8	2,000	+345	
Do. [7]	do	925	6-4½	100	+138	Flows at 650, 795, and 900 feet.
Conde	do	960	4½	Many.	Flows.	
Doland [7]	do	897	4½	370	+281	
Do	do	957		600	+258	
Frankfort [7]	do	1,008	8-4½	Many.	Flows.	Flows at 803, 864, 945 and 1,000 feet.
Mellette	do	1,065	8-6	1,200	Flows.	
Do. [7]	do	920	6-4½	1,320	+380	
Northville	do	980	9-6	1,900	+359	Flows at 875 and 956 feet.
Redfield [7]	do	964	6¼-4½	1,260	+407	
Do	do	1,025	6	1,900	Flows.	
Turton	do	920	4½	1,300	Flows.	
T. 119, R. 63, sec. 22 [7]	do	958		60	+324	
T. 119, R. 63, sec. 19 [7]	do	930	4½	670	+352	
T. 119, R. 64, sec. 23 [7]	do	993	6-4½	1,300	+311	
T. 119, R. 63, sec. 32 [7]	do	920	4½-3	2,894	Flows.	
T. 117, R. 64, sec. —[7]	do	987		Many.	Flows.	
T. 117, R. 62, sec. 32	do	950	4½	350	Flows.	
T. 116, R. 62, sec. 4	do	895	4½	600	Flows.	
T. 115, R. 61, sec. 7	do	1,050	8-4½	75	+200	
T. 114, R. 63, sec. 26 [7]	do	909		1,200	Flows.	
T. 114, R. 62, sec. 18 [7]	do	1,000	6-4½	150	+288	
T. 114, R. 63, sec. 32 [7]	do	1,150	6-4½	550	+115	
T. 114, R. 62, sec. 30	do	909	4½	1,000	+345	
Fort Randall [8]	Todd	610	4	600	Flows.	
Yankton (Excelsior Mill).	Yankton	493	8	3,000	+120	
Yankton (Fountain Mill). [9]	do	600	6	1,500	+110	
Yankton (Asylum) [9]	do	672	4½	165	+23	
Yankton (city well) [9]	do	942	6	880	+41	

[1] Record, U. S. Geol. Survey, 17th Annual Report, part 2, p. 24.
[2] Ibid., pp. 29-30.
[3] Ibid., pp. 22-23.
[4] Ibid., p. 181.
[5] Record, U. S. Geol. Surv., 18th Annual Report, 1897, part 4, p. 575.
[6] Records, U. S. Geol. Surv., 17th Annual Report, 1896, part 2, pp. 31-33.
[7] Ibid., pp. 19-20.
[8] Ibid., p. 58.
[9] Record, U. S. Geol. Surv., 17th Annual Report, 1896, part 2, pp. 53, 58.

SOUTH DAKOTA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Yankton (College Hill).	do	524	2	2,600	+62	
Yankton (Wilcox well).	Yankton	455	3	330	+127	
Yankton (Donaldson well).	do	525	4½		Flow.	
T. 93, R. 56, sec. 12	do	475	2	6	Flow.	
T. 93, R. 56, sec. 17	do	400	2	500	Flow.	
T. 93, R. 56, sec. 16 [1]	do	500	6-5	1,300	+115	
T. 93, R. 55, sec. 8	do	521	3	350	+113	
T. 93, R. 54, sec. 18 [1]	do	422	3½-3	120	Flow.	
T. 94, R. 55, sec. 19 [1]	do	648	2	4	Flow.	
T. 93, R. 54, sec. 11	do	450	2	80	Flow.	
T. 94, R. 55, sec. 18	do	480	2	55	+23	
T. 94, R. 55, sec. 22	do	522	2	30	Flow.	
T. 94, R. 55, sec. 21	do	435	2	100	Flow.	
T. 94, R. 54, sec. 36	do	495	2	75	Flow.	
T. 95, R. 55, sec. 8	do	535	2	50	Flow.	

PUBLICATIONS RELATING TO DEEP BORINGS IN SOUTH DAKOTA.

Report on Irrigation, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 2, pp. 40–65, Washington, 1893.

Preliminary Report on the Artesian Waters of a Portion of the Dakotas, by N. H. Darton, United States Geological Survey, Seventeenth Annual Report, 1895–96, part 2, pp. 609–694, Washington, 1896.

New Development in Well Boring and Irrigation in South Dakota, by N. H. Darton, United States Geological Survey, Eighteenth Annual Reports, 1896–97, part 4, pp. 567–615, Washington, 1897.

Geology and Water Resources of a portion of Eastern South Dakota, by J. E. Todd, United States Geological Survey, Water-Supply and Irrigation Papers, No. 34, 34 pages, plates and maps, Washington, 1900.

TENNESSEE.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bells	Crockett	1,100				Prospect well; unsuccessful.
Chattanooga	Hamilton	600	10-8	50	—45	
Crockett Mills	Crockett	+900	3		No flow.	Abandoned.
Dull (2 miles from)	Dickson	565	4½			Three oil wells.
Do	do	2,000	4½			Oil well.
Dyersburg [2]	Dyer	600		140	Flows.	Do.
Do	do	600		130		Do.
Glen Mary (2 miles west). [3]	Scott	1,236-1,340				Oil wells; several others in Scott County.
Do	do	600				
Helenwood(?)	do	1,500				For oil; unsuccessful.
Hurricane Creek [2]	Union(?)	530				Oil well.
Iron City	Lawrence	400	12			For oil or gas.
Do	do	480				For gas; not in use.
Kingston Springs	Cheatham	1,000				Unsuccessful.
Knoxville	Knox	2,100				Temp. 57°.
Memphis	Shelby	450-400	8-6	200-100		Several wells.
Do. [4]	do	+1,156				
Do	do	3,000-2,000				Several wells for oil; abandoned.
Rugby	Morgan					Several wells for oil.
Saltillo	Hardin	950	36-6	Many.	Flows.	Sulphur; temp. 45°; bored in 1830.
Tullahoma	Coffee	700				Oil well.

[1] Record, U. S. Geol. Surv., 17th Annual Report, 1896, part 2, pp. 53,58.
[2] Tennessee, Comm'r Ag. Rept., Oil Region, 1877, pp. 54, 73.
[3] U. S. Geol. Surv., 17th Ann. Rept., 1895–96, part 3, pp. 699–700.
[4] Tennessee, State Board of Health, Bulletin, vol. 5, 1890, pp. 98–106.

TEXAS.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Abbott (1½ miles N.)	Hill	446		20	−160	
Do	do	486		Several.	−186	
Abilene	Taylor	2,500				
Albany	Shackelford	400		Few.		
Alta Loma	Galveston	875-950	9	310	22	Numerous wells. Temp. 75°-78°.
Alvarado	Johnson	1,500			Flows.	
Alvin (4 miles north)	Brazoria	502	2	70		
Aquilla	Hills	600		Few.	Flows.	
Do	do	800		Several.	Flows.	
Archer City	Archer	550	6	Few.	−50	Alkali water.
Do.[1]	do	736			No flow.	
Do	do	500				Salt water only.
Arcola	Fort Bend	+910		300	Flows.	
Argyle (1½ miles east)	Denton	500			Flows.	Soft water.
Arlington	Tarrant	1,480		21		Strong mineral water.
Aul[2]	Bexar	673			−4	
Austin (Fifth and Jacinto streets).[3]	Travis	2,020		175	Flows.	
Austin (asylum)	do	1,280				
Austin (poorhouse)	do	1,300		5	No flow.	
Austin	do	471		5		
Do	do	1,450		5		
Austin (East Fifth street).	do	700		14	Flows.	In progress 1897; sulphur water.
Austin (Natatorium)[4].	Travis	2,025	10-8-7-6	175	Flows.	Main flow at 1,875 feet; temp. 100°.
Austin (Asylum)[4]	do	1,975		+104	+40	
Austin[4]	do	2,053			−5	
Do	do	1,280				
Austin (near)	Kinney	400				Several wells.
Baileyville	Milan	800				Failure.
Baileyville (3 miles west).	do	831			No flow.	Water very salty.
Baird	Callahan	415	8			Abandoned.
Bastrop	Bastrop	+900				No water.
Barstow	Ward	+500			No flow.	
Batesville	Zavalla	700			−300	
Bedford (2 miles S.)	Tarrant	602½			Flows.	Soft water.
Belcherville	Montague	900-1,200		70	Flow.	Three wells; soft water.
Belton (9 miles W.)	Bell	700			Flows.	
Belton (10 miles SE.)	do	1,800		Many.	Flows.	
Belton (2 miles NE.)	do	1,000			Flows.	
Belton (19 miles W.)	do	530			Flows.	
Belton (9 miles SW.)	do	772		70	Flows.	
Belton[5]	do	975	4	173.6	Flows.	Soft water.
Belton (1 mile SW.)	do	1,060		347	Flows.	Do.
Belton (1 mile S.)	do	1,000			Flows.	
Big Spring	Howard	603	7			Salt water at 300 feet; abandoned.
Birdville	Tarrant	406			No flow.	Soft water.
Birdville (1 mile N.)	do	486			−20	Do.
Birdville (one-half mile from).	do	420		Many.	Flowed once.	
Blum (4½ miles E.)	Hill	532			−200	
Bolivar	Denton	1,176			Flows.	
Bonham	Fannin	+400				
Do	do	+400				
Do	do	1,500				No water.
Bowie	Montague	700			−160	
Bowie (one-half mile west).	do	600				
Boyce (1½ miles west)	Ellis	981		1½	Flows.	Soft water.
Do	do	975			Flows.	Do.
Brackettville (7 miles from).[6]	Kinney	404		Several.		
Brambleton	Tarrant	485			−130	Do.
Branchville (4 miles east).	Milan				Flows.	
Do	do	700			−6	
Breckenridge	Stephens	1,400				Failure.

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 262, Washington, 1890.
[2] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, p. 272, Washington, 1898.
[3] Ibid., pp. 280-283.
[4] U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, pp. 280, 284, Washington, 1898.
[5] Record, Artesian waters of Texas west of the 97th meridian, by R. T. Hill, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 3, p. 116, Washington, 1893.
[6] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, part 2, p. 278, Washington, 1898.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bremond	Robertson	1,500			No flow.	Some water.
Brenham	Washington	600				Failure.
Brownville (50 miles northwest).	Hidalgo	70			No flow.	
Brownwood (northeast of).	Brown	1,900				Oil borings; some gas.
Brownwood	do	1,938	10-6	32	+74	
Do	do	1,558				Failure.
Do	do	1,803				Do.
Bruceville	McLennan	1,560	6		+125	
Do	do	1,565		139	Flows.	Soft water; temp. 95°.
Bryan (16 miles south).	Burleson	870	2	22	Flows.	
Bryan (12 miles from)	do	835	2	35	+30	Temp. 85°.
Do	do	635	2	22	+25	Temp. 76°.
Do	do	550	7	15	+20	Do.
Burke	Angelina	500				Salt water; abandoned.
Burleson (1 mile west).	Johnson	500			No flow.	Soft water.
Burleson (2½ miles west).	do	465		Many.	No flow.	Do.
Call	Newton	700		Several.	Flows.	
Calvert[1]	Robertson	460			−30	
Do.[2]	do	585-620	4	Many.	Flow.	Several wells.
Calvert (5 miles southwest).	do	510	1	Many.	Flow.	Several wells in vicinity.
Do	do	900	1		−20	
Calvert (5 miles west)	do	400			−20	
Do	do	800			−100	
Cayote (3 miles northeast).	Bosque	439			No flow.	
Cedar Bayou	Harris	558	3			
Do	do	600	3		Flows.	
Do	do	727	3	5	Flows.	Temp. 76°.
Do	do	610	3	30		Do.
Cedar Hill (19 miles southwest).	Dallas	750		Many.	−300	Soft water.
Celina	Collin	470		7.7	−145	Do.
Celina (1 mile west)	do	400			−100	Do.
China Springs	McLennan	1,380			Flows.	Another flow at 800 feet; temp. 102°.
Do	do	1,100		40	Flow.	Two (?) wells.
Cisco	Eastland	1,680	8		−25	Salt water.
Clarksville	Red River	1,060			Flows.	Brackish water; abandoned.
Do	do	+1,050			−10 to −12	Salty water.
Do	do	+1,200				Abandoned.
Cleburne	Johnson	970-1,003		70	−40 to −70	Many wells.
Cleburne (6 miles south).	do	520		Many.	No flow.	Soft water.
Cleburne (5 miles southeast).	do	568			−168	Do.
Cleburne (3 miles southwest).	do	420		Many.	−160	Do.
Cleburne (3 miles northwest).	do	424		Many.	−274	
Clifton	Bosque	640		170	Flows.	
Do	do	700		Many.		Temp. 70°.
Clifton (3 miles N.)	do	662		220	Flows.	Temp. 84°; soft water.
Clifton (1 mile west)	do	715		60	Flows.	Soft water.
Clifton (3½ miles N.)	do	670		170	Flows.	
Clifton (8 miles SE.)	do	840		170	Flows.	
Clifton (3 miles W.)	do	612			Flows.	Do.
Clifton (1 mile W.)	do	687			Flows.	Do.
Clifton	do	700		Many.		Temp. 70°.
Clifton (three-fourths mile west).	do	700		11	Flows.	Soft water.
Colorado[3]	Mitchell	1,120				Several deep salt wells.
Commerce	Hunt	2,300				
Comstock (20 miles from).[4]	Valverde	569				

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 266, Washington, 1890.
[2] Record, Texas Geol. Surv., 4th Ann. Rept., 1892, p. 109.
[3] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, p. 265, Washington, 1898.
[4] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 284, Washington, 1890.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Coperas Cove	Coryell	1,865			−100	Brackish water.
Coperas Cove (4 miles north).	do	500		Many.	No flow.	Salty water.
Coperas Cove	do	1,875			−475	
Cornhill	Williamson	404			−282	
Corpus Christi	Nueces					
Do	do	1,765		50		Mineral water at about 600 feet only.
Do	do	525		300		
Do	do	560		100		
Corsicana	Navarro					
Corsicana (3 miles west).	do	2,500				
Corsicana	do	2,477				Several wells.
Do	do	1,000-1,200				Many oil wells.
Do	do	2,483		208	+150	Water, gas, and oil; temp. 126°.
Do	do	2,150		208		Oil at 1,100 feet.
Do	do	2,487		Many.		
Do	do	2,500		+194.4	+85	Temp. 126° F.
Do	do	1,035				Oil well.
Corsicana (3 miles west).	do	2,300				
Coryell (3 miles east)	Coryell	940		Many.	−50	Soft water.
Cotulla[1]	Lasalle	825			Flows.	Bad water.
Do	do	1,010		55.5		
Do	do	852				
Do	do	800		2	Flows.	Do.
Do	do	1,008		Many.	+6	Temp. 86° F.; alkaline-saline water.
Cotulla (8 miles S.)	do	600			−100	Bad water.
Crawford (4 miles west).	McLennan	1,000		31		Soft water.
Do	do	1,040		31		Do.
Do	do	945		140		Temp. 72° F.; two wells.
Do	do	1,060		50		Soft water.
Crockett	Houston	630	5-3	Many.	−190	
Crowley	Tarrant	486		3	No flow.	Soft water.
Crowley (3 miles northwest).	do	446			−150	Do.
Crowley (7 miles southwest).	do	430			No flow.	Do.
Crowley (2 miles from).	do	484	2		−134	Do.
Cyrus (1 mile east)	Bosque	1,000		Many.	Flows.	
Dallas (1 mile east)	Dallas	850		70	Flow.	Two wells.
Dallas (6 miles west-northwest).	do	+400		Many.	Flows.	
Dallas	do	790-1,000		Many.	Flows.	Numerous wells.
Do	do	718			Flows.	Much soda in water.
Do	do	700		12	Flows.	
Dallas (City Park)	do	672		15	Flows.	
Dallas	do	±2,500				
Dallas (1 mile south)	do	850		70	Flow.	Two wells.
Dallas (6 miles west-northwest).	do	±400		Many.	Flows.	
Davenport	Guadalupe	810			−180	Good water.
Del Rio[2]	Valverde	760			−60	Mineral waters.
Del Rio (30 miles N.)	do	475			−300	
Del Rio (3 miles S.)	do	460			Flows.	Sulphur water,
Denison (1 mile S.)[3]	Grayson	1,800	2½			Abandoned.
Denton	Denton	460			+15	
Do	do	550	6	6	+20	
Do	do	600		Few.		
Do	do	620		8	Flows.	
Do	do	600			Flows.	
Do	do	606		28	Flows.	
Derby	Frio	540		Many.	−35	
Dickinson[4]	Galveston	600	3	14	Flows.	
Do	do	624	3	40	Flows.	
Dickinson (3 miles W.)	do	700	3	34.7	Flows.	
Dickinson (one-fourth mile west).	do	588	1		Flows.	
Dryden	Pecos	1,797	7¾-4	18	−600	

[1] Texas, Geol. Surv., 2d Ann. Rept., 1891, p. 71; Analysis, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 272, Washington, 1890.
[2] U S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, pp. 265, 299, Washington, 1898.
[3] Record, ibid., 21st Annual Report, 1899-1900, part 7, p. 197, Washington, 1901.
[4] Analysis, Texas Geol. Surv., 4th Ann. Rept., 1892, p. 104.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Dryden	Pecos	590		Many.	-539	
Dublin	Erath	400			-8	
Eagleflat	El Paso	680				No water.
Eagleford	Dallas	417		800	+35	Soft water.
Eagle Pass[1]	Maverick	1,508				Salty water.
Do	do	400				Abandoned.
Eastland[2]	Eastland	500				Abandoned.
Do	do	1,300	6		No flow.	Salt water.
Do	do	400			Flows.	Mineral water.
Eden	Concho	987		7	Flows.	Salty water.
Do	do	800				Oily water; abandoned.
Eddy	McLennan	1,565		208	Flows.	Soft water.
El Paso (NW. of)	El Paso	800				In granite; no water.
El Paso (10 miles NE.)[3]	do	621			−215	
Encinal	Webb	900			−200	Good water.
Enon	Tarrant	442			−142	
Enon (1 mile west)	do	430		5	−60	
Enon (3 miles NE.)	do	460		Many.	−90	Soft water.
Estelle	Dallas	970			Flow.	Soft water.
Eulogy	Bosque	780		34	Flows.	
Do	do	529		30	Flows.	
Eulogy (1 mile north)	do	475			Flows.	Do.
Eulogy (three-fourth mile north)	do	460		10	Flows.	
Eulogy (one fourth mile west).	do	430		68	Flows.	Do.
Fairwood[4]	Galveston	575	3	50	Flows.	Temp. 78½°.
Farr (2 miles south)	McLennan	1,065		10	Flows.	
Ferris	Ellis	1,360		89	Flows.	
Finlay[5]	El Paso	1,080	8			Bad water at 396 feet; abandoned.
Forreston	Ellis	400				No water.
Fort Bliss Station		403	4½	Many.	−130	
Fort Worth[6]	Tarrant					
Do	do	484			−50	
Do	do	450				
Do	do	465		30	Flows.	
Do	do	950–1,400	10 to 4	140	Flow.	Several wells.
Do	do	4,000				No flow below 1,200 feet; temp. 140° at 3,250 feet.
Do	do	760				
Fort Worth (3 miles north).	do	1,200				
Fort Worth (10 miles east).	do	480	4½	+208		
Fort Worth (12 miles southeast).	do	534			−450	
Fort Worth (7 miles south).[7]	do	+400				
Fowler (1½ miles N.)	Bosque	735		123	Flows.	Soft water.
Frankfort (2 miles southwest).	Collin	442			−50	Salty water.
Franklin	Robertson	1,200			No flow.	
Freeland (2 miles S.)	Johnson	500		15	Flows.	Soft water.
Freeland (2½ miles S.)	do	618		18	Flows.	
Freeland (1½ miles S.)	do	585		65	Flows.	Good water.
Freeland (1½ miles W.)	do	548		12	Flows.	Soft water.
Gainesville	Cooke	±1,250			− 40	In progress.
Do	do	850		243	− 10	
Do	do	480			− 40	
Do	do	405		69	No flow.	
Do	do	632		Many.	− 7	
Do	do	700			− 30	
Do	do	850		6		
Galveston[8]	Galveston	3,070	22–6	Many.	Flows.	Brackish water at various depths to bottom.
Do	do	1,346		400	Flows.	Salty water.

[1] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 266, Washington, 1890.
[2] Ibid., pp. 268, 269.
[3] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 297, Washington, 1890.
[4] Analysis, Texas Geol. Surv., 4th Ann. Rept., 1892, p. 102.
[5] Analysis, 51st Congress, 1st session. Senate Ex. Doc. No. 222, p. 272, Washington, 1890.
[6] Record, Artesian Waters of Texas west of 97th meridian, by R. T. Hill, 52d Congress, 1st session, Senate Ex. Doc. No. 41, Part 3, pp. 105–106, Washington, 1893.
[7] Fifty-first Congress, 1st session, Senate Ex. Doc. No. 222, p. 270, Washington, 1890.
[8] Records, analysis, etc., Texas Geol. Surv., 4th Ann. Rept., 1892, pp. 87–101; U. S. Geol. Survey, 21st Annual Report, 1899–1900, part 7, pp. 402–406, Washington, 1901.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet	*Inches.*	*Gallons.*	*Feet.*	
Galveston	Galveston	810-973		Many.	Flow.	Several wells; water too salty.
Galveston (2½ miles west).	do	1,365		250	Flows.	Temperature 84°.
Gatesville	Coryell	500-550	6	2-20	Flow.	Several wells.
Do	do	700		175		
Do	do	475			No flow.	Soft water.
Gatesville (8 miles W.)	do	612				Do.
Gatesville (6 miles southeast).	do	558		4	Flows.	
Georgetown (2 miles east).	Williamson	520		15		
Godley (5 miles S.)	Johnson	420		Many.	No flow.	Do.
Goldthwaite	Mills	563	10-7		− 20	
Do	do	600				
Do	do	563	10-7		− 20	
Gonzales	Wilson	1,400		15	+ 60	Flows at 650, 950, 1,300, and 1,400 feet.
Do	do	625	10-8	30	Flows.	
Gonzales (1 mile N.)	do	1,135		Many.	− 60	
Gordon	Palo Pinto	485		1	+ 23	Salt water.
Do	do	498	1	1	+ 23	Salt water and gas.
Grapevine	Tarrant	423			No flow.	Soft water.
Gravis (1½ miles S.)	Williamson	412		3	−96	Sulphur water.
Greenway (one half mile west).	Johnson	590		45		Soft water.
Greenway (one-half mile northwest).	do	602		22	Flows.	Do.
Hamilton	Hamilton	425				Water only at 350 feet to −8 feet.
Handley	Tarrant	509			−25	Soft water.
Hallettsville	Lavaca	300-560			Flow.	
Harmosa	McLennan	1,730		139		Soft water; temp. 103°.
Hartley	Hartley	410	5	17		
Haskell	El Paso	2,029	12-7⅝	Few.	No flow.	
Haslett (1 mile S.)	Tarrant	430			−255	Soft water.
Haslett (3 miles SE.)	do	480		3	−258	
Hearne	Robertson	740			Flows.	Many wells in vicinity.
Do	do	400-450	4		Flow.	Several wells.
Do	do					
Do	do	450-700	2	3 to 10	+10-+40	Do.
Hearne (8 miles S.)	do	300-700		3	Flows.	
Hearne (12 miles northwest).	do	300-700		3	Flows.	
Heffron	Galveston	480	3	52	+16	Temp. 60° ±
Hemming	Cooke	426		100	Flows.	Soft water.
Hico	Hamilton	1,365	12		−125	Water at 210, 300, 600, and 900 feet.
Do	do	1,200			No flow.	
Hidalgo	Hidalgo	700			−100	
Hillsboro	Hill	1,800			Flows.	
Do	do	1,762		34.7	Flows.	
Do	do	500				Failure.
Hitchcock[1]	Galveston	726		66	Flows.	Temp. 77°; many wells in vicinity.
Hitchcock (1½ miles northwest).	do	710		100	Flows.	Temp. 77°.
Do	do	768		48	Flows.	Temp. 78°.
Holland (10 miles S.)	Bell	1,800		10	Flows.	Salt water.
Honeygrove	Fannin	1,700		Many.		Strong mineral water.
Do	do	1,650		Many.	− 50	Do.
Do	do	1,500				
Do	do	1,000			−300	Salty water; not in use.
Do	do	1,200			No flow.	
Hondo	Medina	1,000				No water.
Do	do	1,500		Many.	−175	
Houston	Harris	493	8	120	Flows.	
Do	do	564	8	130	Flows.	
Do	do	850	5	200	Flows.	
Do	do	500 or less.			Flows.	Fine water.
Do	do	700				
Houston (3 miles from).	do	600		42		Temp. 70°.
Hubbard	Hills	3,166			Flows.	

[1] Analyses, etc., Texas Geol. Surv., 4th Ann. Rpt., 1892, pp. 102-103.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Hueco	El Paso	431				Bad water; abandoned.
Hueco (20 miles NNE.)	do	572		Many.		Bad water.
Humble	Harris	606	3½	50	Flows.	Fresh water.
Huntsville	Walker	2,210	9-3	Many.	−100	
Hurst Lake	Coryell	500				
Italy	Ellis	1,400		¼	− 10	Soft water.
Itasca	Hills	1,800			Flows.	
Do	do	1,680		160	+ 35	
Jefferson	Marion	802		Few.	Flows.	Sulphur water.
Joshua (3 miles west)	Johnson	525			No flow.	Soft water.
Joshua (6 miles NW.)	do	424			−189	
Kaufman	Kaufman	450				Failure.
Kaufman (1 mile NW.)	do	600				Do.
Kearnes	Kearnes	1,800				Do.
Keechi	Jack	400		1/40	−400	Soft water.
Keene	Johnson	750			−300	Do.
Keller	Tarrant	400				
Do	do	457		50	−50	
Do.[1]	do	430				
Keno	Liberty	700				No water below 90 feet; abandoned.
Kerrville	Kerr	1,325			−75	Good water at 750 feet.
Kerrville (9½ miles northeast).[2]	do	1,100		Several.	−55	Granite below 180 feet.
Killeen	Bell	606			−60	
Kimball	Bosque	550-630			Flow.	Several wells.
Kimball (6 miles west)	do	564		60	+20	Soft water.
Kopperl	do	400		½	Flows.	
Kopperl (¾ mile east)	do	600		800	Flows.	Do.
Kopperl	do	625		150	Flows.	Slightly brackish.
Kopperl (3½ miles W.)	do	609		200		
Kopperl	do	525			Flows.	
Krum (2½ miles south)	Denton	450			No flow.	
Ladonia	Fannin					
Do	do	1,033				Never completed.
Lancaster	Dallas	1,057			Flows.	Soft water.
Lanham	Hamilton	470				Abandoned.
Do	do	500				Do.
Do	do	600				
Lanoria[3]	Mesa	621			−215	
Laporte	Harris	454	3	41	Flows.	
Do	do	440	3	80	Flows.	
Laredo	Webb	1,200			No flow.	
Lebanon	Collin	400		Many.	−100	
Llano (9 miles SE.)	Llano	500			+2	Coal prospect; abandoned.
Longfellow	Pecos	683	8	20	No flow.	
Lorena	McLennan	1,495		Many.	Flows.	Soft water.
Lorena (5 miles west)	do	760		Few.	Flows.	Salt water.
Lorena	do	1,495		Many.	Flows.	Soft water.
Lozier	Pecos	770	7⅝	Few.	No flow.	
Lufkin	Angelina	1,300				No water; abandoned.
Manor[4]	Travis	2,220	6	69	+30	Temp. 93°.
Marine (½ mile NE.)	Tarrant	1,200		545	Flows.	Temp. 78°; soft water.
Marlin	Falls	3,350		140	+322	Temp. 147°.
Marshall	Harrison	1,000			No flow.	
Maxon Springs	Buchel	1,004	9½-4½	Several.		Not in use.
Maysfield	Milam	1,356	4	Many.	−34	
McGregor	McLennan	1,030		139	−10	Soft water.
Do	do	470			Flows.	
Do	do	991		348		
McGregor (5 miles west.)	do	490		Many.	−11	Do.
McKinney	Collin	1,860		21	−70	Soft water.
Menardville (near)	Brown	1,100				Found water, etc., but well now caved in.
Menardville	Menard	1,175				Oil boring unsuccessful.
Meridian	Bosque	450-580		25-45	Flow.	Several wells; soft water.
Meridian (10 miles E.)	do	850		16	Flows.	
Meridian (12 miles E.)	do	875			−42	Soft water.

[1] Record, Artesian waters of Texas west of 97th meridian, by R. T. Hill, 52d Congress, 1st session, Senate Ex. Doc. No. 41, Part 3, p. 104, Washington, 1893.
[2] U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, p. 271, Washington, 1898.
[3] Record, 51st Congress, 1st session, Senate Ex. Doc. 222, p. 297.
[4] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part 2, pp. 285-286, Washington, 1898.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Merkel	Taylor	+2,000				
Miami	Roberts	—500				Several wells in county.
Midlothian	Ellis	464			—200	
Milford	do	2,018			Flows.	Mineral water?.
Mineola[1]	Wood	1,200	6-3		—40	
Moody	McLennan	1,508		69	No flow.	Soft water.
Do	do	1,300			No flow now.	
Do	do	1,450			—15	
Morgan[2]	Bosque	600		100	Flows.	Soft water.
Do	do	580-620		20-150	Flow.	Several wells; soft water.
Morgan (1 mile SE.)	do	575		170	Flows.	Soft water.
Morgan	do	800		50	Flows.	
Morgan (5 miles east)	do	780		40	Flows.	
Morgan (12 miles E.)		501		100	Flows.	
Morris Ranch[3]	Gillespie	1,100			—55	
Mound (2 miles NE.)	Coryell	697			—5	Mineral water.
Mountain Peak (¾ mile southwest).	Ellis	435		Many.	No flow.	Soft water.
Mumford	Robertson	300-1,000		2-12		Several wells.
Myers	Burleson	440	1-2	2		Temp. 60°.
Do	do	860	4-2	30	+20	Temp. 90°.
Myrtle Springs	Van Zandt	650				Unsuccessful.
Navasota[4]	Grimes	830			To surface.	
Navasota (16 miles N.)	do	999		Many.	Flows.	
Newlin Station	Hall	550	6			Four layers of salt water; abandoned.
Neri (2 miles south)	Hood	415			No flow.	Soft water.
Newark	Wise	410	5	1	+14	Temp., 65°.
New Boston	Bowie	1,200			—75	
Norse (4 miles SW.)	Bosque	622			No flow.	Soft water.
North Galveston	Galveston	575-1,590	3	70 each.	Flow.	Several wells.
Oak Grove (1 mile S.)	Tarrant	500		3½	—72	Soft water.
Ocee (1 mile east)	McLennan	1,098	6	160	Flows.	Do.
Odessa	Ector	830	8			Abandoned.
Oglesby (2½ miles northwest-west).[5]	Coryell	500			No flow.	Soft water.
Orphans' Home Station (2 miles SE).	Dallas	685			No flow.	Very salty water.
Orphans' Home Station.	do	1,230		20	—40	Mineral water.
Palestine	Anderson	650	6	Few.	—200	
Palestine (1½ miles)	do	444	8-6	121	No flow.	Several wells.
Palmer	Ellis	1,154		+9	Flows.	Soft water.
Do	do	1,154			Flows.	Do.
Do	do	1,178		83	Flows.	Do.
Panhandle City	Carson	600				Unsuccessful.
Paris	Lamar	444				Abandoned.
Do	do	1,350		Many.	—5	
Park Springs	Wise	400	6	Many.	—60	
Pearsall	Frio	600		15	Flows.	
Do	do	400		30	Flows.	
Do	do	650		30	Flows.	
Do	do	620			—29	
Pearsall (15 miles E.)	do				Flow.	Several wells.
Pearsall (20 miles SE.)	do	(?)				
Pecangrove	Coryell	590			Flows.	
Pecos[6]	Pecos	683		20		
Do	do	987		28		Good water.
Do	do	1,797		16		Do.
Do	do	770		16		
Pecos (4 miles W.)	Reeves	400			No flow.	
Pierce Station	Wharton	850 or 900				
Pilotpoint	Denton	937		17	—25	Soft water.
Pilotpoint (8 miles northwest).	Cooke	426		1		Do.
Port Arthur	Jefferson	±800	5		Flows.	Mineral water; temp. 80°.
Pottsboro (7 miles west).	Grayson	±500		Many.	Flows.	Pure water.
Prosper	Collin	470		Many.	No flow.	Soft water.

[1] Geol. Surv. of Texas (Report on the Brown coal and lignite of Texas), pp. 132-135, 1892.
[2] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 269, Washington, 1890.
[3] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II. p. 272, Washington, 1898.
[4] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 265, Washington, 1890.
[5] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 283, Washington, 1890.
[6] Record, etc., U. S. Geol. Surv., 18th Ann. Rept., 1896-97, Part II, p. 267, Washington, 1898.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Prosper (¾ mile east)	Collin	660		4	—244	Soft water.
Quintana	Brazoria	650				
Randol (1 mile NE.)	Tarrant	546			—10	Sulphur water.
Randol (one-half mile southwest.)	do	525		156	Flows.	
Randol (3 miles SW.)	do	420		½	Flows.	Soft water.
Randol (one-half mile north).	do	505	4		Flows.	Do.
Refugio [1]	Refugio	853		104	Flows.	
Refugio	do	956		104	Flows.	
Do	do	1,000		347	Flows.	
Rendon (2 miles N.)	Johnson	535		Many.	No flow.	Do.
Riovista (1 mile NE.)	do	460		Many.	No flow.	Do.
Riovista (3 miles E.)	do	540			—176	Do.
Roanoke (west.)	Denton	476			—33	
Roanoke	do	400–600		40–50	Flows.	Several wells.
Roanoke (one-half mile south).	do	505			—16	
Rocksprings	Edwards	400		Many.	No flow.	Two wells.
Do	do	450		Many.	No flow.	Do.
Rogers	Bell	+1,600			Flows.	
Roundrock	Travis	400		1	No flow.	
Roundrock	Williamson	1,400			—4	
Rusk	Cherokee	620				Abandoned.
Sabinal	Walde	529				
Salado (5 miles SE.)	Bell	412			—397	
San Angelo	Tom Green	960				
San Antonio [2]	Bexar	822–1,200		55–200		Numerous wells.
Do	do	1,250				
Do	do	465		55		
San Antonio (1 mile west).	do	835		55		
San Antonio	do					
Do	do	870		861		
San Antonio (3 miles southeast).	do	1,100				Hot sulphur water.
San Antonio (3 miles south).	do	1,900		555		
San Antonio (6 miles southeast).	do	2,215				Water at 1,800 feet.
San Antonio (2 miles south).	do	1,900		555	—84	
San Antonio	do	500				Several wells.
Do	do	650–715		500–700		Do.
San Antonio (2½ miles northwest).	do	540				
San Antonio	do	630				
Do	do	750–780		1,000		Do.
Do	do	450				
Do	do	657		250		Do.
San Antonio (3 miles north).	do	583			—50	
Sanderson [3]	Pecos	987	7⅝	30	No flow.	
Sanderson	do	2,000				No water.
San Marcos [4]	Hays	1,490		6	Flows.	Waters at 128, 191, 652, 1,178, 1,291, 1,345, and 1,475 feet.
Santa Tomas						
Sherman	Grayson	632				Fine water.
Do	do	915				
Do	do	2,500		Many.	—40	
Do	do	660				Several wells.
Sherman (18 miles N.)	do	480			No flow.	
Sierra Blanco [5]	El Paso	943	5⅝	Many.	No flow.	Bad water.
Sonora	Sutton	480				Several wells.
Do	do	809				Oil.
South Bosque (3 miles west).	McLennan	450		1		
Spofford Junction	Kenney	1,700				Failure.
Stony (1½ miles south)	Denton	447		3	Flows.	Soft water.
Strong Junction	Harris	450	3	48	+9	
Sugarland	Fort Bend	600–1,550	3–4		Flow.	Several wells
Do	do	1,550	8–4	104	+9	
Surfside	Brazoria	1,070	4	215	Flows.	
Taylor	Williamson	1,400		104	Flows.	

[1] Records, 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 266–267, Washington. 1890.
[2] Records, etc., U. S. Geol. Surv., 18th Ann Rept., 1896–97, Part II., pp. 290–297. Washington, 1898.
[3] Record, U. S. Geol. Surv., 18th Ann. Rept., 1896–97, Part II, p 274, Washington, 1898.
[4] Ibid., pp. 287–290.
[5] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 296, Washington, 1900.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Taylor	Williamson	2,800		27	Flow.	Two wells; poor water.
Do	do	1,500		15	+40	Several wells
Temple (1 mile west)	Bell	1,850		Many.	Flow.	Temp. 91°.
Do	do	1,800		Few.	Flows.	
Terrell [1]	Kaufman	2,200	8	70	−50	Good water.
Texas City	Galveston	725		+104	+16	
Do	do	900		+104	+16	
The Grove	Coryell	900		680	−13	
Thorndale	Milan	1,790				No water.
Do	do	3,200				Do.
Thurber [2]	Erath	3,050			No flow.	
Tilden	McMullen	475	4¼	8	Flows.	Salty water.
Timber	Tarrant	576		2½		Do.
Tobey	Atascosa	1,200–1,300				
Torbert	El Paso	1,100	8–5⅝			Abandoned. Small amount of fair water at 696 feet.
Toyah	Reeves	834	9–3	300	Flows.	Sulphur water.
Do	do	514	12	9	Flows.	
Trinity	Trinity	+900		Few.		Salty, sulphur water
Trinity Mills (4 miles east).	Dallas	+468			−25	
Do	do	415			−25	
Troy	Bell	1,472	8		Flows.	Soft water.
Do	do	1,474		14	Flows.	
Do	do	1,464		243	Flows.	Do.
Turtle Bayou	Chambers	850	4	139	Flows.	
Do	do	900	4			
Tyler	Smith	1,150	6			In progress, 1901.
Uvalde	Uvalde	512		Few.	−85	
Do	do	1,000			No flow.	
Valda	Polk	420	4	45	Flows.	
Valentine	Presidio	1,280				No water.
Do	Jeff Davis	1,245	5⅝–3	Many.	No flow.	
Valeo	Hidalgo	1,004	8			No water below.
Valley Mills	Bosque	805			Flows.	
Valley Mills (5 miles north).	do	870			Flows.	Soft water.
Valley Mills (1 mile north).	do	706			Flows.	
Valley Mills (5 miles north).	do	877			Flows.	Do.
Van Horn	El Paso	600	5⅝		−500	Several wells.
Velasco	Brazoria	1,100	8	694	Flows.	
Vernon [3]	Wilbarger	(?)				
Do	do	(?)				
Victoria	Victoria	815–956		70–200	Flow.	Three wells.
Waco [4]	McLennan	1,812–1,862	8–4	51–400	Flow.	Numerous wells. Temperature, 103°.
Waco (5 miles west)	do	1,470	4⅝	347	Flows.	Pure water. Temperature, 90°.
Waldo (2 miles south)	Coryell	423			−85	Saline water.
Wallisville	Chambers	400		70		
Walters	Travis	700				
Waxahachie	Ellis	990			Flows?	
Do	do	1,700			−15	Soft water.
Waxahachie (6 miles southwest).	do	700			−125	
Weatherford [5]	Parker	500			−50	
Do	do	402		69	−250	Good water.
Do	do	440				
Do	do	488			−250	
Webb	Tarrant	800			−160	Poor water.
West	McLennan	1,690		208	Flows.	
Wexia	Limestone	1,333	4½			Oil or gas prospect; abandoned; some water at 512 feet.
Whitesboro	Grayson	+800			No flow.	
Whitney	Hill	1,575			+40	
Do	do	1,000		139	Flows.	
Do	do	438			430	
Wichita Falls (1½ miles south).	Wichita	800				Salt water.

[1] Record, Artesian waters in Texas west of 97th meridian, by R. T. Hill, 52d Congress, 1st session, Senate Ex Doc. No. 41, part 3, p. 99. Another authority gives 2,700 feet as depth.
[2] Record, 51st Congress, 1st session, Senate Ex. Doc. No. 222, p. 270, Washington, 1890.
[3] Analysis, Texas Geol Surv., 4th Ann. Rept, 1892, p 105
[4] Record, 51st Congress, 1st session, Senate Ex. Doc No. 222, pp. 265, 269, Washington, 1890. Analysis, ibid., p. 271.
[5] Record, 51st Congress, 1st session, Senate Ex Doc. No. 222, p. 266, Washington, 1890.

TEXAS—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Wills Point	Van Zandt	1,100	6		To surface.	
Youngsport	Bell	404		1	Flows.	
Do	do	417		½	Flows.	
Youngsport (1¼ miles east).	do	433		¾	Flows.	
Youngsport (one-half mile north).	do	444		1	Flows.	
Zimbi [1]	Harris	480				No water; abandoned.
Do	do	520				Do.

PRINCIPAL PUBLICATIONS RELATING TO THE UNDERGROUND WATERS OF TEXAS.

Report of F. E. Roesler, Division Field Agent for Texas, letter from the Secretary of Agriculture transmitting a report on the preliminary investigations to determine the proper location of artesian wells within the area of the 97th meridian and east of the foothills of the Rocky Mountains, 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 243–319, Washington, 1890.

Report of E. T. Dumble on the existence of artesian waters west of the 97th meridian, etc., 51st Congress, 1st session, Senate Ex. Doc. No. 222, pp. 99–102, Washington, 1890.

Preliminary reports on the artesian wells of the Gulf Coastal Slope, by J. A. Singley, Texas Geological Survey, 4th Annual Report, 1892, pp. 85–113, Austin, 1893.

On the occurrence of artesian and other underground waters in Texas, etc., west of the 97th meridian, by R. T. Hill, Report on Irrigation, 52d Congress, 1st session, Senate Ex. Doc. No. 41, part 3 (Final Geological Reports), pp. 41–166, plates, Washington, 1893.

Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters, by Robert T. Hill and T. Wayland Vaughan, United States Geological Survey, Eighteenth Annual Report, 1896–1897, part 2, pp. 193–321 and plates, Washington, 1898.

Geography and geology of the Black and Grand prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters, by Robert T. Hill, United States Geological Survey, Twenty-first Annual Report, 1899–1900, part 7, pp. 1–649, Washington, 1901.

UTAH.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Bountiful	Davis	400		4–60		
Bountiful (2 miles north of west).	do	580				No water.
Layton	do	500	4½–1¼	Few.		
Paragonah	Iron	412	2			Cool water.
Salt Lake City	Salt Lake	550	8	500		
Do	do	1,105	8	350		
Salt Lake City (12 miles north).		500–750				Several wells.
Smithfield	Cache	410		3		

[1] Record, etc., Texas Geol. Surv., 4th Ann. Rpt., 1892, p. 107.

UTAH—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Spanish Fork	Utah	420	2	60		
Do	do	400	2	5		
Do	do	400	2	70		
Do	do	410	2	40		
Sulphur Springs		650			No flow.	
Vernal	Uinta	975				Abandoned.
Do	do	900	8			Surface water only.

VIRGINIA.

Alexandria (brewery).	Alexandria	430	8	90		
Alexandria (ice works).	do	401	8	20		
Allisonia	Pulaski	400-1,200				Several wells.
Blueridge Springs	Botetourt	500	6	75		
Buckroe Beach		+400				
Claybank	Gloucester	538	1	Several.	Flows.	
Cotman	Henrico	730		40	No flow.	In granite.
Covington	Alleghany	1,138		400		
Crewe	Nottoway	500		Few.	Flow.	
Delton	Pulaski	+400		Not any		Abandoned.
Ditchley		620	1	2	Flows.	
Dublin	Pulaski	475	6	25	−80	
Dymer Creek [1]	Northumberland.	507				
Fairport [2]	do	662	8-6	75	Flows.	
Fort Monroe [3]	Elizabeth City.	907				Drilled in 1864; saline water flowed at 591 feet.
Do. [4]	do	945			Flows.	Saline water.
Foster Falls	Wythe	808		100	−2	
Harrisonburg	Rockingham	420	8		−10	
Gloucester	Gloucester	600		Not any		
Lamberts Point [5]	Norfolk	616		65	+ 7	
Lancaster	Lancaster	+400			No flow.	
Middlebrook	Augusta	460	5	10	−50	
Newport News	Warwick	600		Few.	No flow.	
Norfolk (Money Point).	Norfolk	562		Many.	Flows.	Ferruginous water.
Norfolk (water works). [6]	do	1,760	12-4½	150	Flows.	Saline waters at several horizons.
Northend Point [7]	Elizabeth City.	1,172		Not any		
Oak Springs		400	1	Several.	Flows.	
Pulaski	Pulaski	400-600	6	100	−10	Several wells.
Do	do	1,200				
Reedville	Northumberland.	680	8-6	85	+ 3	Temp. 78°.
Richmond (paper mill).	Henrico	400		Several.		
Richmond (Sherwood Park).	do	900		Not any		
Richmond (Ginter Farm).	do	400		Many.		
Roanoke	Roanoke	1,200	6		− 4	Not in use.
Roanes [8]	Gloucester	716	6	50	+23+	
Stanardsville	Greene	1,150				For oil. No success.
Staunton (asylum)	Augusta	696	5	60	−60	
Staunton (mile east)	do	460	5	9	−30	
Sandy Point [9]	Fairfax	560		Many.	No flow.	Water at 270 feet; rock below.
Stonega	Wise	503	8	55	−16	
Toms Creek			6	100	No flow.	
Williamsburg	James City	876		Not any	do	
Windmill Point	Lancaster	450				Abandoned.

[1] Record, U. S. Geol. Surv., Bull. No. 138, p. 176.
[2] New Jersey Geol. Surv., Report for 1898, pp. 121-122.
[3] Record, Geology of the Virginias, by W. B. Rogers, New York, 1884, pp. 731-736; Am. Inst. Mining Engineers Trans., vol. 24, pp. 380-384; U. S. Geol. Surv., Bull. No. 138, p. 167.
[4] Record, etc., New Jersey Geol. Surv., Report for 1898, pp. 122-126.
[5] Record, U. S. Geol. Surv., Bull. No. 138, p. 172; New Jersey Geol. Surv., Report for 1899, pp. 87-92.
[6] Record, etc., New Jersey Geol. Surv., Report for 1899, pp. 92-102.
[7] Record, Am. Inst. Mining Eng., Trans., vol. 24, pp. 384-386.
[8] New Jersey Geol. Surv., Report for 1899, pp. 86-87.
[9] Record, U. S. Geol. Surv., Bull. No. 138, p. 178.

PRINCIPAL PUBLICATION RELATING TO DEEP WELLS IN VIRGINIA.

Artesian Well Prospects in the Atlantic Coastal Plain Region, by N. H. Darton, United States Geological Survey, Bulletin No. 138, 232 pages, 19 plates, Washington, 1896.

WASHINGTON.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Junction City	Jefferson	800	1¾	¾	Flows.	Abandoned.
North Yakima [1]	Yakima	404	6	Many.	Flows.	
Do	do	534-835	8, 6 and 3.	Many.	Flow.	Several wells.
Do	do	650		Many.	Flows.	Temp. 71°.
Do	do	1,050	5-3½		+110	
Do	do	940	6-4		Flows.	
Pasco [2]	Franklin	527 404	6	Many.	Flows.	
Do	do	400		Not any		
Port Blakely	Kitsap	410	4½	500	—6	
Prosser	Yakima	500		Many?	No flow.	
Port Discovery	Jefferson	+800				Abandoned.
Roslyn	Kittitas	700		Many.	Flows.	
Port Discovery (4 miles northeast).		1,230				
Port Townsend	Jefferson	1,060				For coal; unsuccessful.
Port Townsend (3 miles from).	do	1,500				Do.
Port Townsend (9 miles from).	do	1,100				Do.
Port Townsend (15 miles from).	do	700				Do.
Port Townsend (18 miles from).	do	900				Do.

WEST VIRGINIA.

Alva [3]	Tyler	2,700				For oil or gas.
Beaver Creek, (1 mile north).		417				
Big Flint Creek (2 miles southeast from mouth). [4]	Doddridge	2,520				Oil well.
Big Otter	Clay	1,100				Do.
Booher [5]	Tyler	1,859				Several gas wells.
Bridgeport	Harrison	±2,500				Two oil wells.
Brink (near) [6]	Wetzel	2,753				For oil or gas.
Browns Mills (near) [7]	Harrison	1,867				For oil; unproductive.
Buckhannon	Upshur	2,530				For oil.
Buffalo (near)	Putnam	400				
Bulltown	Braxton	1,000				Salt well.
Burning Springs (near). [8]	Wirt	2,010				Oil well.
Burnsville	Braxton	2,750				Small flow of oil.
Cairo [9]	Ritchie	2,060				For oil or gas.
Cairo (1½ miles northwest) [10]	do	1,735				Do.
Cairo (4 miles northeast). [11]	do	2,142				Do.
Cairo (8 miles south). [12]	do	1,652				Small supply of oil.
Cameron (near) [13]	Marshall	3,249				For oil or gas.
Center Point (near). [14]	Doddridge	1,910-2,880				Several oil wells.
Central	do	460	5		—20	Sulphur water.

[1] Records, U. S. Geol. Surv., Bull. No. 108, pp. 56-58, Washington, 1893.
[2] Record, ibid., p. 39.
[3] Record, W. Va. Geol. Surv., Report, vol. 1, p. 336.
[4] Ibid., pp. 332-334.
[5] Ibid., p. 358.
[6] Ibid., p. 345.
[7] Ibid., pp. 249-250.
[8] Ibid., pp. 262-263.
[9] Ibid., p. 302.
[10] Ibid., pp. 303-304.
[11] Ibid., pp. 305-307.
[12] Ibid., pp. 308-309.
[13] Ibid., p. 350.
[14] Ibid., pp. 328-332.

WEST VIRGINIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Central City	Cabell	2,900	8¼-6¼	Many.	Flows.	Some oil.
Do.[1]	do	2,770				Small flow of gas.
Central City (vicinity).	Boyd	1,675-1,775				Two oil wells.
Charleston (waterworks).[2]	Kanawha	1,840				For oil or gas; unproductive.
Charleston (8 miles above).[3]	do	2,450				Moderate flow of gas.
Charleston (9 miles above).[4]	do	2,542				Small flow of gas.
Charleston (13 miles southwest).[5]	do	2,000				For oil or gas; unproductive.
Cherry Camp (vicinity).[6]	Harrison	2,556-2,839				Several oil and gas wells.
Clarksburg	do	1,700		Many.	Flows.	Some gas.
Clarksburg (5 miles east).	do	2,000				
Clarksburg (4 miles south).	do	750		Many.	Flows.	Salt water.
Clifton	Mason	1,800			—100	
Cross Creek district[7]	Brooke	765				For oil; unproductive.
Dingess Station (near).[8]	Mingo	2,126				For oil or gas.
Eagle Mills (?)(near)[9]	Tyler	2,922				Do.
Ellenboro (3½ miles from).[10]	Ritchie	1,782-1,828				Several oil and gas wells.
Eureka (near)[11]	Pleasants	1,348+ 1,602				Two oil wells.
Fairfax (northwest of).[12]	Mingo	1,338				For oil or gas.
Fairview (southwest of).[13]	Marion	1,889				Oil well.
Fairview (2 miles northeast).[14]	do	1,997				For oil; unproductive.
Fallsmill	Braxton	1,000				Salt well.
Farmington Station (2 miles east).[15]	Marion	2,811				For oil or gas; abandoned.
Friendly (near)	Tyler					Deep well for oil or gas.
Glenville[16]	Gilmer	2,412	7⅜			Oil and gas well.
Do	do	800	2			For oil or gas; abandoned.
Grant district[17]	Hancock	1,470				For oil; unproductive.
Do.[18]	Wetzel	3,044				Gas well.
Harpers Ferry	Jefferson	412		Few.	No flow.	
Harrisville	Ritchie	1,600-2,000				Several oil wells.
Harrisville (near)[19]	do	2,500				Oil well.
Hart (near)[20]	Lincoln	3,260				For oil or gas.
Hebron (near)[21]	Pleasants	2,080				Do.
Henry	Preston	703	4			
Highland Church (near).[22]	Monongalia Marion line.	3,484	10-5			Oil well.
Holbrook (near)[23]	Ritchie	2,670				Oil well.
Hundred (near)[24]	Wetzel	3,249				Gas well.
Huntington	Cabell	2,975	8¼-6¼			Oil prospect; unsuccessful; much water at bottom.
Do	do	1,200	8-6			
Iuka (near)	Tyler					Several oil wells.
Jarvisville	Harrison	2,500-2,800				Numerous oil wells.

[1] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 275-276.
[2] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 331-332.
[3] Ibid., p. 330.
[4] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 271-272.
[5] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 332-333.
[6] Records, W. Va. Geol. Surv., Report, vol. 1, pp. 252-255.
[7] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5] pp. 327-328.
[8] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 278-280.
[9] Ibid., pp. 334-335.
[10] Ibid., pp. 311-315.
[11] Ibid., pp. 351-352.
[12] Ibid., pp. 276-277.
[13] Ibid., pp. 239-241.
[14] Ibid., pp. 238-239.
[15] Record, Pa. 2d Geol. Surv., Ann. Report for 1886, part 2, pp. 782-783.
[16] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 259-260.
[17] Record, Pa. 2d Geol. Surv., Reports, Vol I[5], p. 328.
[18] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 340-342.
[19] Ibid., p. 319.
[20] Ibid., pp. 280-281.
[21] Ibid., p. 360.
[22] Ibid., pp. 231-232.
[23] Record, W. Va. Geol. Surv., Report, vol. 1, p. 320.
[24] Ibid., p. 349.

WEST VIRGINIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Joetown (1 mile W.)[1]	Marion	3,014				For oil or gas.
Kanawha (and vicinity).[2]	Kanawha	1,000-2,450				Numerous salt and gas wells.
Kenton (?) (vicinity).[3]	Doddridge	2,115				For oil or gas.
Letart (near)[4]	Mason	2,139				Do.
Liberty Township[5]	Marshall	2,934				For oil or gas, unproductive.
Long Run Station (near).[6]	Doddridge	2,701				For oil or gas.
Lot (near)[7]	Wetzel	2,588				Do.
Loudensville (5 miles north).[8]	Marshall	1,935				Do.
Lightburn (vicinity)	Lewis	2,700				For oil or gas; abandoned.
Little Mills (near)[9]	Tyler	2,690				For oil or gas.
Macksburg (near)[10]	Noble	1,695				Do.
Malden[11]	Kanawha	1,800				Gas well.
Mannington (near)[12]	Marion	1,928				For oil or gas.
Mannington (1 mile above).[13]	do	3,144				Do.
Mannington (3 miles southwest).[14]	do	3,042				Do.
Mannington (3 miles north).[15]	do	2,895				Oil well
Mannington (6 miles northwest).[16]	do	3,010				Do.
McKim (near)[17]	Tyler	1,942				For oil or gas.
Martinsburg	Berkeley	485				Abandoned.
Do	do	450				
Metz (near)[18]	Marion	2,992				For oil or gas.
Middlebourne (few miles below).[19]	Tyler	1,562				Small supply of oil.
Middlebourne (4 miles north).[20]	do	1,638				Oil well.
Miletus (near)[21]	Doddridge	2,930				For oil or gas.
Do	do	2,670				Gas well.
Morgantown[22]	Monongalia	2,267				For oil or gas.
Moundsville (near)[23]	Marshall	1,470				Do.
Moundsville (vicinity).	do	1,400-1,413				Several oil wells.
Moundsville (3 miles northeast).[24]	do	578				Numerous oil wells.
Murphytown (vicinity).[25]	Wood	2,177				For oil or gas.
Newburg	Preston	3,009				For gas; unsuccessful.
Do	do	865			—18	
New Cumberland	Hancock	+600				Gas well.
New Cumberland (2 miles east).[26]	do	1,198				Oil well.
Oxford[27]	Ritchie	2,106				Do.
Oxford (7 miles above)[28]	Doddridge	2,484				Do.
Parkersburg (near)[29]	Wood	2,035				For oil or gas.
Parkersburg (5 miles northeast).[30]	do	3,016				Do.
Peoria	Harrison	2,300				Do.

[1] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 345-347.
[2] Records, Pa. 2d Geol. Surv., Reports, Vol. I[5], pp. 329-333; W. Va. Board of Centennial Managers, Resources, Report by Maury and Fontaine, pp. 287-290.
[3] Record, W. Va. Geol. Surv., Report, vol. 1, p. 335.
[4] Ibid., pp. 281-282.
[5] Record, Pa. 2d Geol. Surv., Report, Vol. I[5], pp. 328-329.
[6] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 325-326.
[7] Ibid., p. 339.
[8] Ibid., 351-352.
[9] Ibid., p. 355.
[10] Ibid., pp. 298-299.
[11] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 331.
[12] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 241-242.
[13] Ibid., pp. 242-243.
[14] Ibid., pp. 243-244.
[15] Ibid., pp. 244-246.
[16] Ibid., pp. 246-247.
[17] Ibid., p. 359.
[18] Record, W. Va. Geol. Surv., Report, vol. 1, p. 348.
[19] Ibid., p. 361.
[20] Ibid., p. 360.
[21] Ibid., pp. 323-324.
[22] Record, Pa. 2d Geol. Surv., Reports, Vol. I[5], p. 329.
[23] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 362-363.
[24] Ibid., p. 364.
[25] Ibid., pp. 292-294.
[26] Ibid., p. 369.
[27] Ibid., pp. 321-322.
[28] Ibid., pp. 322-323.
[29] Ibid., p. 285.
[30] Ibid., pp. 296-298.

WEST VIRGINIA—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Petroleum Station (1½ miles north).[1]	Ritchie	1,800				Oil well.
Piney Fork[2]	Wetzel	2,640				For oil or gas.
Poe District[3]	Hancock	1,700				For oil; unproductive
Point Pleasant (6 miles below).[4]	Mason	2,942				For oil or gas.
Ravenswood (near)[5]	Jackson	2,232				Do.
Ritchie Court-House.[6]	Ritchie	1,724-1,918				Several oil and gas wells.
Ronceverte	Greenbrier	800				For oil; abandoned.
Salem	Harrison	2,100-2,800				Oil wells.
Sardis (vicinity)[7]	do	3,081				For oil; abandoned.
Sedalia (near)[8]	Doddridge	2,800				Large gas well.
Shanghai	Berkeley	714	7	Few.		Sulphur water at 188 feet; abandoned.
Sisterville (near)	Tyler					Large oil well.
Sistersville (2½ miles southwest).[9]	do	1,865				For oil or gas.
Smithfield (near)[10]	Wetzel	3,282				Oil well.
Smithfield (2 miles northeast).[11]	do	3,106				Do.
Spencer (asylum farm).[12]	Roane	2,750				For oil or gas.
Spencer (about 10 miles southwest).[13]	do	1,623-2,362				Several oil and gas wells.
Sutton (1½ miles below).[14]	Braxton	2,725				Oil well.
Ten Mile District[15]	Harrison	2,750				For oil or gas; unproductive.
Vadis (near)[16]	Lewis	2,703				Oil well.
Do.[17]	Doddridge	2,207				For oil; unsuccessful on account of water.
Wadestown (near)[18]	Monongalia	3,090				Oil well.
Do.[19]	do	3,112				Do.
Do.[20]	do	3,300	6?			Gas well.
Waverly (6 miles south).[21]	Wood	2,261-2,208				Two oil wells.
Wellsburg[22]	Brooke	1,217				Numerous deep gas wells; now run out.
Do.[23]	do	1,310				Gas well.
Weston	Lewis	2,700				For oil; unsuccessful
Do	do	1,450				Small flow of oil.
Weston (2 miles below).	do	2,165?				Gas well.
Weston (10 miles southeast).[24]	do	2,401				Oil well.
Wick (near)[25]	Tyler	1,915				For oil or gas.
Williamstown (1½ miles below).[26]	Wood	1,504-1,673				Do.
Williamstown (4 miles below).[27]	do	710-1,138				Two oil wells.
Winfield (?)	Putnam	500				Two wells.
Wheeling[28]	Ohio	2,095				For oil or gas.
Wheeling (near).[29]	do	4,500	4⅝			Do.
Wheeling (3 miles east-northeast).[30]	do	2,000				For oil or gas; unsuccessful.
Wordley (near)[31]	Monongalia	2,830-2,960				Gas well.

[1] Record, W. Va. Geol. Surv., Report, p. 301.
[2] Ibid., p. 337.
[3] Record, Pa. 2d Geol. Surv., Reports, Vol. I5, p. 327.
[4] Record, W. Va. Geol. Surv., Reports, vol. 1, pp. 273-274.
[5] Ibid., pp. 283-284.
[6] Ibid., pp. 317-318.
[7] Ibid., pp. 248-249.
[8] Ibid., pp. 326-327.
[9] Record, W. Va. Geol. Surv., Report, vol. 1, p. 357.
[10] Ibid., p. 343.
[11] Ibid., pp. 343-344.
[12] Ibid., pp. 264-266.
[13] Ibid., pp. 267-269.
[14] Ibid., 269-270.
[15] Ibid., p. 251.
[16] Ibid., pp. 257-258.
[17] Ibid., pp. 258-259.
[18] Ibid., pp. 233-234.
[19] Ibid., pp. 232-233.
[20] Ibid., pp. 230-231.
[21] Ibid., pp. 292-294.
[22] Record, Ohio Geol. Surv., Report, 1888, Vol. VI, pp. 337-339.
[23] Record, Pa. 2d Geol Surv., Ann. Report for 1886, part 2, pp. 783-784; W. Va. Geol. Surv., Report, vol. 1, p. 367.
[24] Record, W. Va. Geol. Surv., Report, vol. 1, pp. 255-256.
[25] Ibid., p. 359.
[26] Ibid., pp. 290-291.
[27] Ibid., p. 289.
[28] Ibid., p. 366.
[29] Ibid., pp. 364-365.
[30] Record, Pa. 2d Geol. Surv., Ann. Report, 1886, part 2, pp. 781-782.
[31] Record, W. Va. Geol. Surv., Report, vol, 1, pp. 234-237.

PRINCIPAL PUBLICATIONS RELATING TO DEEP BORINGS IN WEST VIRGINIA.

West Virginia Geological Survey, Reports, vol. 1, by I. C. White, 392 pages, Morgantown, 1899.

Seventh Report on the Oil and Gas Fields of Western Pennsylvania for 1887–1888. Pennsylvania Second Geological Survey, Vol. I[3], by J. F. Carll, 356 pages, Harrisburg. 1890.

WISCONSIN.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Berlin	Green Lake	425	6	40	+3	Temp. 52°.
Do	do	450		40	+3	
Bristol	Kenosha	815	5		−32	
Brodhead	Green	1,000	4–8	Each 150	+12	Two wells. Water from 250–300 feet mainly. Granite, 700–1,000 feet. Temp. 52°.
Burlington	Racine	1,000	9	Many.	Flows.	
Do	do	800	9	Many.	−8	
Cassville	Grant	1,100	6	Many.	Flows.	
Clinton	Rock	650		Many.	−30	
Dale	Outagamie	490		Many.	−15	
De Soto	Vernon	466	6	126	+26	Temp. 52°.
Durand	Pepin	550	6	180	+35	Good water.
Durand (5 miles southeast).	do	402	10–6	2	−282	Do.
East Troy	Walworth	2,200			No flow.	
Elkhorn	do	1,050	8–6	Many.	−155	
Elroy	Juneau	500 or 600			No flow.	Not in use.
Fond du Lac	Fond du Lac.	750	10	Many.	−10	Two wells.
Do	do	600	10	Many.	−10	Do.
Do	do	480	10	Many.	−10	
Do.[1]	do	425				
Genoa	Vernon	460	6	200	−30	
Greenbay	Brown	950		70	+14	Temp. 53°. Several wells.
Hartford	Washington	920		40		To be deepened.
Haven	Sheboygan	600			−40	
Do	do	420			−11	
Hudson	St. Croix	400–500				
Independence	Trempealeau	438			−12	Well in bad order; abandoned.
Jamesville[2]	Rock	1,100–1,033	8	500	+35	Two wells and magnesia; water to +48 at 683 feet.
Jamesville (fair ground).	do	±1,100		Not any	No flow.	Abandoned.
Kilbourn	Columbia	1,320				
La Crosse[3]	La Crosse	573	6	100	−16	Some lime and iron; city supply.
Madison	Dane	736–821	10	Many.	+5	Several wells. Temp. 51°.
Marinette	Marinette	716	4	Many.	+21	Water at 405 and 415 feet only; granite at 716 feet. Temp. 49°.
Menomonee Falls	do	1,700	8	Many.	Nearly to top.	
Millville	Grant	487	7	Several	−369	
Milwaukee[4]	Milwaukee	1,048	4	Many.	+60	
Milwaukee (near)[5]	do	1,200		300	+50	
Monroe	Green	+400				
Oconto	Oconto	+400		450	+24	Temp. 50°.
Oil City[6]	Monroe	510		Many.	+25	Main body of water at 300 feet.
Onalaska	La Crosse	450		284	To surface.	
Oshkosh[7]	Winnebago	961	6	Many.	−4	Granite below 700 feet.

[1] Record, Wis. Geol. Surv., Reports, 1873–1877, vol. 2, p. 153.
[2] Ibid., pp. 166–197.
[3] Record, Wis. Geol. Surv., Reports, 1873–1879, vol. 4, pp. 60–61.
[4] Record, Wis. Geol. Surv., Reports, 1873–1877, vol. 2, p. 164.
[5] Analysis, ibid., p. 164.
[6] Record, Wis. Geol. Surv., Reports, 1873–1879, vol. 4, pp. 59–60.
[7] Record, Wis. Geol. Surv., Reports, 1873–1877, vol. 2, p. 156.

WISCONSIN—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Oshkosh[1]	Winnebago	695	6	Many.	−1	Granite below 665 feet.
Do	do	537	5	Many.	−1	
Oshkosh (normal school).	do	613	5	Many.	−4	
Oshkosh	do	505	5	Many.	−1	Several other similar wells.
Palmyra[2]	Jefferson	750			−14	Water at 263 feet; oil at 257 feet.
Patch Grove	Grant	487	9-6	Several	−440	Good water; two other similar wells in vicinity.
Platteville	do	1,000				
Prairie du Chien[3]	Crawford	960	8-5½	600	+60	Temp. 56°. Water slightly salty; brine at 514 feet; several wells.
Racine[4]	Racine	1,240		Many.	+65	Several wells.
Do	do	1,350	4	Many.	+92	
Richland Center	do	750	6	2,400	−11	
Riverfalls	Pierce	500	8-6	200	−6	No water below 400 feet.
Do	do	400	8-6	200	−6	
Rock Elm	do	520	8		−120	Abandoned.
Sheboygan[5]	Sheboygan	1,475	4	225	+104	Temp. 59°. Flow at 1,340 feet.
Sherwood	Calumet	1,035				
Superior	Douglas	927	6			Water brackish.
Tornado	Door	1,040	8-6	Many.	−122	
Tomar[6]	Monroe	492			No flow.	
Two Rivers	Manitowoc	1,700	8	Many.	No flow.	Abandoned; granite in bottom.
Urne	Buffalo	471	6			
Watertown	Jefferson	1,145	9	600	+11	Temp. 47°.
Waukesha	Waukesha	1,000-1,500			−35	Several wells.
Westbend	Washington	1,500		Many.	−4	
West Depere	Brown	810	5	250	+26	Temp. 65°
Western Union Junction.[7]	Racine	1,263		Few.	+40	
Whitewater	Walworth	950		200	+20	

PUBLICATIONS RELATING TO DEEP BORINGS IN WISCONSIN.

Wisconsin Geological Survey, Reports, 1873-1877, vol. 2, part 2, pp. 97-405.
Wisconsin Geological Survey, Reports, 1873-1879, vol. 4, part 1, 98 pages.

WYOMING.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Aladdin	Crook	±1,000				No water.
Almond	Sweetwater	1,000				Strong sulphur water.
Cambria[8]	Weston	1,300				In progress.
Cheyenne	Laramie	1,145				
Clifton (north of)[9]	Weston	1,002		Few.	Flows.	Mineral water.
Dallas	Fremont	800-1,200			Flow.	Oil wells.
Douglas	Converse	500			+20	Some oil; much water.
Gillette	Crook	865			−485	
Hilliard	Uinta	484				For oil; unsuccessful.

[1] Ibid., p. 156.
[2] Ibid., pp. 161-162.
[3] Record, Wis. Geol. Surv., Reports, 1873-1879, vol. 4, pp. 61-62.
[4] Record, Wis. Geol. Surv., Rpts., 1873-1877, vol. 2, p. 163.
[5] Record and analysis, ibid., p. 164.
[6] Record, Wis. Geol. Surv., Rpts., 1873-1879, vol. 4, p. 60.
[7] Record, Wis. Geol. Surv., Rpts., 1873-1877, vol. 2, pp. 162-163.
[8] Record, U. S. Geol. Survey, 21st Ann. Rept., 1889-1900, part 4, p. 572.
[9] Ibid., p. 571.

WYOMING—Continued.

Location.	County.	Depth.	Diameter.	Yield per minute.	Height of water.	Remarks.
		Feet.	*Inches.*	*Gallons.*	*Feet.*	
Jerome[1]		520				
Judson	Albany	540		Few.	Flows.	Sulphur water.
Laramie	do	1,015		30	Flows.	Good water.
Do	do	1,470				
Leach	do	510	5		No flow.	
Moorcroft (8 miles northwest).	Crook	1,300				For oil; unsuccessful.
Moorcroft (10 miles northwest).	do	800				Two small oil wells.
Mullen	Fremont	1,200		Several.		Oil and sulphur water.
Newcastle	Weston	1,950		Several.	Flows.	For oil; unsuccessful.
Do	do	1,340				Some oil at about 400 feet.
Do	do	420				Some oil.
Newcastle (3½ miles southwest).	do	720				No product.
Oil City[2]	Natrona	1,130				Oil and gas.
Oxford Ranch	Albany	540		Few.	Flows.	For oil; unsuccessful.
Rawlins	Carbon	450	4½	200		Several wells.
Do	do	487		400	Flowed originally.	
Do	do	928		350	Flowed originally.	Water from 466 feet.
Salt Creek oil field[3]	Natrona	809-1,200				Oil wells.
Sheridan	Sheridan	500	2½	¼		
Sussex	Johnson	1,300		Few.		Water at 358 and 1,120 feet.

PUBLICATIONS RELATING TO DEEP BORINGS IN WYOMING.

Petroleum of Salt Creek, Wyoming, by W. C. Knight, University of Wyoming, petroleum series, Bulletin No. 1, 47 pages, June, 1896.

Petroleum of the Shoshone Anticlinal, by W. C. Knight, University of Wyoming, petroleum series, Bulletin No. 2, 34 pages, January, 1897.

Oil Fields of Crook and Uinta Counties, Wyoming, by W. C. Knight, University of Wyoming, Petroleum series, Bulletin No. 3, 31 pages, November, 1899.

A Preliminary Report on the Artesian Basins of Wyoming, by W. C. Knight, University of Wyoming, Wyoming Experiment Station, Bulletin No. 45, 251 pages, plates, map, June, 1900.

Preliminary Description of the Geology and Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming, by N. H. Darton, United States Geological Survey, Twenty-first Annual Report, 1899–1900, [illegible] Contains [illegible] maps, Washington, 1901.

F. H. Newell, and [illegible]

[illegible] alysis, ibid., p. 571.

[illegible] Record, etc., Wyo., Ann. Rept. Geologist, Jan., 1888, p. 32.

[3] Record, Wyoming University, Bull. No. 1 (Petroleum series), 1896, pp. 18–19.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, New York, to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nin[illegible]th Annual Report of the United States Geological Survey, 1897–98, Part [illegible]graphy, 1899; octavo, 814 pp.

[illegible]eport of progress of stream measurements for the calendar year 1898," by [illegible]others; "The rock waters of Ohio," by Edward Orton; and "A prelimi-[illegible]ology and water resources of Nebraska west of the one hundred and [illegible]. Darton.

[illegible]h Annual contains a paper on "Principles and conditions of the [illegible]" by F. H. King, and one on "Theoretical investigation of the [illegible]motion [illegible]rs, [illegible]C. S. Slichter.

1900.

Twentieth Annual Repor[illegible] the United States Geological Survey, 1898–99, Part IV, Hydrography, 19[illegible]vo, 660 pp.

Contains a "Report of [illegible] of stream measurements for the calendar year 1898," by F. H. Newell, and "Hyd[illegible]y of Nicaragua," by A. P. Davis.

1901.

Tw[illegible]-first Annual Report of the United States Geological Survey, 1899–1900, Part IV, Hydrography, 1901; octavo, 768 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton; and "The High Plains and their utilization," by W. D. Johnson.

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The Director, United States Geological Survey, Washington, D. C.

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Ariz., by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colo., by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Underground waters of southeastern Nebraska, by N. H. Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.

15, 16. Operations at river stations, 1897, Parts I, II, 1898.

17. Irrigation near Bakersfield, Cal., by C. E. Grunsky, 1898.
18. Irrigation near Fresno, Cal., by C. E. Grunsky, 1898.
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21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of the Bighorn Mountains, by Elwood Mead, 1899.

24, 25. Water resources of the State of New York, Parts I, II, by G. W. Rafter, 1899.

26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.

27, 28. Operations at river stations, 1898, Parts I, II, 1899.

29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the Lower Peninsula of Michigan, by Alfred C. Lane, 1899.
31. Lower Michigan mineral waters, by Alfred C. Lane, 1899.
32. Water resources of Porto Rico, by H. M. Wilson, 1900.
33. Storage of water on Gila River, Arizona, by J. B. Lippincott, 1900.
34. Geology and water resources of southeastern S. Dak., by J. E. Todd, 1900.

35–39. Operations at river stations, 1899, Parts I–V, 1900.

40. The Austin dam, by Thomas U. Taylor, 1900.

41, 42. The windmill: its efficiency and use. Parts I, II, by E. C. Murphy, 1901.

43. Conveyance of water in irrigation canals, etc., by Samuel Fortier, 1901.
44. Profiles of rivers, by Henry Gannett, 1901.
45. Water storage on Cache Creek, California, by Albert E. Chandler, 1901.
46. Reconnoissance of Kern and Yuba rivers, California, by F. H. Olmsted and M. Manson, 1901.

47–52. Operations at river stations, 1900, Parts I–VI, 1901.

53, 54. Geology and water resources Nez Perce Co., Idaho, Pts. I, II, by I. C. Russell.

55. Geology and water resources of Yakima Co., Wash., by G. O. Smith.
56. Methods of stream measurement, 1901.
57. Deep borings in United States, Part I, by N. H. Darton, 1902.
58. Storage of water on King River, California, by J. B. Lippincott, 1902.

59, 60. Wells of southern California, Parts I, II, by J. B. Lippincott, 1902.

61. Deep borings in United States, Part II, by N. H. Darton, 1902.

Other papers are in various stages of preparation. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Stat. L., vol. 29, p. 453.]

The endeavor is made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests made for a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent.

Application for these papers should be made either to members of Congress or to

THE DIRECTOR, UNITED STATES GEOLOGICAL SURVEY, WASHINGTON, D. C.

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DEPARTMENT OF THE INTERIOR

J. L. LUDLOW, C. E. M. S.
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WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

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No. 62

HYDROGRAPHY OF THE SOUTHERN APPALACHIAN MOUNTAIN REGION, PART I.—PRESSEY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 62

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

HYDROGRAPHY

OF THE

SOUTHERN APPALACHIAN MOUNTAIN REGION

PART I

By HENRY ALBERT PRESSEY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

J. L. LUDLOW, C. E. M. S.
M. Am. Soc. C. E.
WINSTON, N. C.

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., December 18, 1901.

SIR: I have the honor to transmit herewith a manuscript prepared by Mr. H. A. Pressey, one of the hydrographers of this Survey, relating to the Southern Appalachian mountain region. This is the outcome of systematic measurements of the water supply from this area and of special investigations made in connection with a general inquiry as to the importance of the streams in the development of the country.

There has been a widespread movement for the acquisition by the Government of the forested lands within the Southern Appalachians and the setting aside of these as a reserve similar in character to the great forest reservations existing in the West. In this popular movement Prof. J. A. Holmes, State geologist of North Carolina, has been especially active. He has been cooperating with this Survey in all matters pertaining to the investigations in North Carolina, and has been the representative of the State in arranging for the disbursement of funds made available by the State for extending the systematic work carried on in that region. At his suggestion and with his active assistance the surveys and examinations described by Mr. Pressey have been made.

The importance of a full knowledge of this region is apparent when we consider the size and number of the streams issuing from this central mountain area. Water-power development, especially in the manufacture of cotton, is proceeding rapidly, and there is no portion of the country for which definite official data upon the water resources are more frequently required than for this area. I recommend, therefore, that the material prepared by Mr. Pressey be published in the series of Water-Supply and Irrigation Papers, as Nos. 62 and 63 of that series.

Yours respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

MAP
OF
SOUTHERN APPALACHIAN
MOUNTAINS
Scale
WEST VIRGINIA
VIRGINIA
BLUE RIDGE
GREAT SMOKY MTS
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
Whiteside Mt
ATLANTA
COLUMBIA
Charlotte
Lexington
Wadlington
Ellijay
Dallas
Marietta
Cartersville
Rome
Gainesville
Dalton
Chattanooga
Knoxville
Asheville
Hendersonville
Morganton
Lenoir
Wilkesboro
Mocksville
Salisbury
Concord
Monroe
Wadesboro
Hamlet
Cheraw
Chesterfield
Camden
Sumter
Darlington
Hartsville
Winnsboro
Chester
Lancaster
Kershaw
Newberry
Saluda
Greenville
Spartanburg
Gaffney
Shelby
Rutherfordton
Marion
Morganton
Hickory
Statesville
Mocksville
Lexington
Thomasville
Greensboro
Reidsville
Danville
Martinsville
Stuart
Galax
Wytheville
Bristol
Abingdon
Tazewell
Pikeville
Hazard
Whitesburg
Jenkins
Pineville
Middlesboro
Harlan
Cumberland
Corbin
Somerset
Stanford
Danville
Frankfort
Lexington
Winchester
Richmond
Berea
Mt Sterling
Paris
Cynthiana
Maysville
Ashland
Catlettsburg
Huntington
Ironton
Portsmouth
Chillicothe
Athens
Pomeroy
Gallipolis
Jackson
Wellston
Logan
Nelsonville
Zanesville
Cambridge
Coshocton
Newark
Mansfield
Ashland
Wooster
Canton
Akron
Cleveland
Elyria
Sandusky
Toledo
Fremont
Tiffin
Bucyrus
Marion
Delaware
Columbus
Springfield
Dayton
Xenia
Chillicothe
Circleville
Lancaster
Newark
Zanesville
Steubenville
Wheeling
Parkersburg
Charleston
Huntington
Ashland

HYDROGRAPHY OF THE SOUTHERN APPALACHIAN MOUNTAIN REGION.

PART I.

By Henry A. Pressey.

INTRODUCTION.

The region herein described occupies portions of the States of Virginia, North Carolina, South Carolina, Tennessee, Georgia, and Alabama. It is elevated far above the surrounding country and stands out as a physiographic unit. Its rivers, topography, and resources are described in as much detail as the time available for field investigation permitted.

Special thanks are due to Mr. E. W. Myers, resident hydrographer for North Carolina and South Carolina, for his investigations and very complete reports on several of the drainage areas, the principal facts from which are embodied herein. Messrs. Cleveland Abbe, jr., L. V. Branch, N. C. Curtis, and Ernest Graves were also engaged upon the reconnaissance, and the success achieved was largely due to their assistance. The measurements of the streams to the south and west of the French Broad were under the charge of Prof. B. M. Hall, resident hydrographer for Georgia and Alabama, who was assisted by Max Hall, W. E. Hall, J. R. Hall, J. C. Conn, and H. G. Stokes. The photographs used for illustrations were taken by various members of the United States Geological Survey and of the United States Bureau of Forestry. Pls. IX and XI are from photographs by R. H. Scadin, Pls. XXXIX and XLII are by courtesy of Prof. J. A. Holmes.

GENERAL FEATURES OF REGION.

MOUNTAINS.

PHYSIOGRAPHY.

The great Appalachian mountain system stretches from Maine, in a general southwesterly direction for nearly 1,300 miles, through the States of Vermont, New York, Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, and Tennessee, terminating in northern Alabama. In New York the range consists of high hills, the mountains gradually rising in elevation in Pennsylvania, where an

average height of 2,000 feet above the sea, or 1,000 to 1,500 feet above the adjacent Cumberland Valley, is reached. At Potomac River, in the vicinity of Harpers Ferry, the elevation of the peaks is again reduced to about 800 feet. From the Potomac south the ranges are much higher and broader, spreading out into the great Blue Ridge, the Shenandoah, the Allegheny, and the Greenbriar mountains, ranges with broad, fertile valleys between, of which the Valley of Virginia, or Shenandoah Valley, has a national reputation for scenic beauty and fertility. Forty-five miles below the Potomac is Mount Marshall, 3,150 feet high, and a little farther south, near Luray, are Stoneyman and Hawks Bill, 4,031 and 4,063 feet high, respectively. These are the highest summits of the Blue Ridge north of North Carolina. The ranges extend in nearly parallel lines through the States of Virginia and West Virginia, and enter North Carolina and Tennessee near their common boundary, culminating in the Iron and the Great Smoky ranges, which with numerous cross chains form the great mountain region of the Southeastern States. In this mountain mass 288 peaks exceed a height of 5,000 feet, and 27 peaks have an elevation greater than Mount Washington (6,293 feet). From North Carolina and Tennessee the ranges extend more to the westward through Georgia and into Alabama, with outlying ranges in South Carolina, and are finally lost in hills forming the headwaters of the Gulf drainage. The general features of the southern and most massive portion of the Appalachians, with the drainage, are shown in Pl. I.

This great mountain system forms the backbone and watershed of the eastern part of the United States. The greatest masses and the highest peaks are in western North Carolina and eastern Tennessee, which region may be considered a high plateau, of which the Smoky Mountains form the western boundary of the highest portion and the Blue Ridge the eastern boundary. The latter ridge extends across the State of North Carolina in a general northeast-southwest direction until it reaches the southern border of the State, when it turns to the west and for a long distance (about 40 miles) forms a part of the boundary between North Carolina and South Carolina, passing at length into the State of Georgia and meeting again the Great Smoky Range. The area of the region included between these two ranges, which approaches to almost a point at its northern and southern extremes and at its widest portion has a width of 55 miles, is approximately 6,000 square miles.

The most striking characteristic of the Blue Ridge is the great difference in slope of its opposite sides. The rivers flowing to the west into the Tennessee and the Ohio head in the gaps upon the divide and for miles flow in broad, smoothly rounded, drift-filled valleys before entering the narrow, rock-cut gorges of their lower courses, while the rivers flowing to the east plunge downward in a series of cascades, falling several thousand feet in a distance of a few miles. The latter

streams can hardly be said to have valleys, but simply V-shaped gorges, through which they tumble and foam until they reach the Piedmont Plain, which extends along the southeastern base of the Appalachian system. The surface of this plain has a general eastward slope from an altitude of about 1,000 feet at its western edge to 250 or 300 feet on the east, where it merges into the Coastal Plain.

The Smoky Mountains, on the western edge of the high plateau referred to, are extended to the north in the Bald and the Iron mountains and to the south in the Unaka Range. These mountains are much more massive and reach far greater elevations than the summits of the Blue Ridge. Many of their peaks attain heights of more than 6,000 feet. Unlike the Blue Ridge, their slopes are equally steep on both sides, their outlines are angular and rugged, and descents of 4,000 feet from the crest to the stream bed are not uncommon.

Several cross chains connect the Smoky and Blue Ridge ranges, cutting the plateau into a number of small basins, each nearly surrounded by mountains and having its own independent system of rivers and drainage, so that nowhere in this region do we find extended fertile valleys, as in Virginia and Tennessee, but instead in every direction high mountain ranges cut off the view and give it the appearance of a rocky and truly mountainous country.

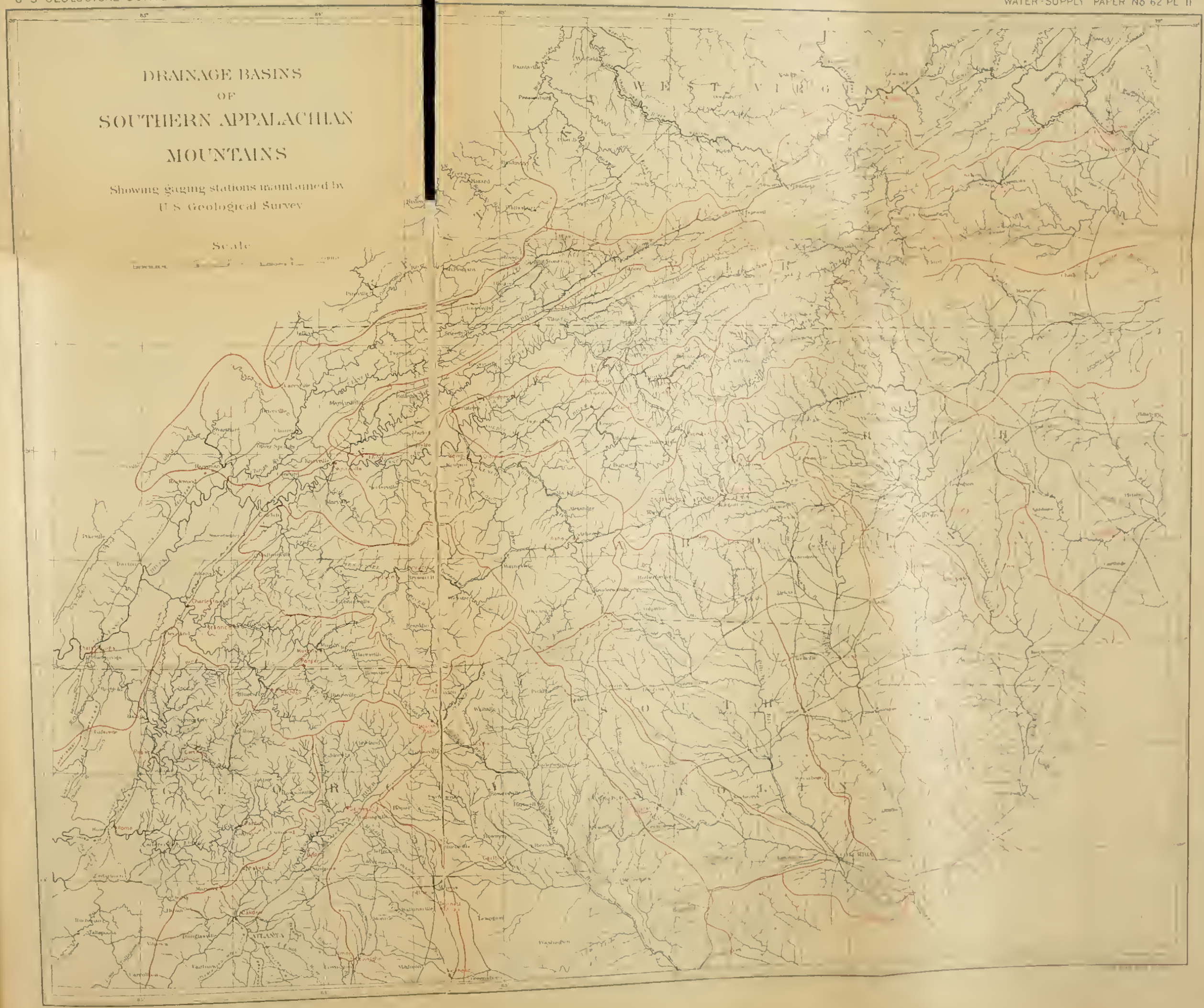
The highest and most massive of the cross chains is the Black Mountains—named for their somber vegetation of balsam and other evergreens—which really consist of two chains having a united length of 40 miles and extending in a northwesterly direction from the Blue Ridge through the counties of Buncombe and Yancey and forming a connecting link between the Blue Ridge and the Smoky mountains. This range of mountains comprises 25 peaks, 18 of which are more than 6,000 feet in height. On their western slopes rise the eastern tributaries of the French Broad, the valley of which separates the Black Mountains from the Pisgah and the Newfound mountains, other of the cross chains, on the western slopes of which rise the eastern tributaries of Pigeon River. The western tributaries of the Pigeon flow from the Balsam Mountains, a range having an average elevation of 5,600 feet and comprising 23 summits with elevations exceeding 6,000 feet. This range extends from the South Carolina line to the Smoky Mountains. Still farther to the west are the Cowee Mountains, with a mean height of 4,800 feet. Rising at the southern end is Yellow Mountain, with an elevation of 5,133 feet. The last of the cross ranges to the west is the massive double chain of the Nantahala and the Valley River mountains, with a mean height of 5,000 feet. East of the Black Mountains are the Linville Mountains, through which Linville River has cut its stupendous chasm.

The Smoky and the Blue Ridge mountains, with their numerous cross chains, form the culmination of the Appalachian mountain sys-

tem, and are the highest and most massive mountains in the United States east of the Rockies. Following is a list of the peaks which exceed in elevation 6,000 feet:

Highest peaks in Southern Appalachians.

	Feet.
Smoky Mountains:	
Mount Buckley	6,599
Clingmans Dome	6,660
Mount Love	6,443
Mount Collins	6,188
Mount Alexander	6,447
Mount Henry	6,373
Mount Guyot	6,636
Tricorne Knob	6,188
Ravens Knob	6,230
Thermometer Knob	6,157
Luftee Knob	6,232
Cataloochee Mountain	6,159
Roan High Knob	6,313
Roan High Bluff	6,287
Grassy Ridge (bald)	6,226
Mount Curtis	6,568
Mount Leconte	6,612
Master Knob	6,013
Oconee Mountain	6,135
Peck Peak	6,232
Mount Safford	6,535
Balsam Mountains:	
Enos Plotts Balsam	6,090
Jones Balsam	6,224
Rockstand Knob	6,002
Brother Plott	6,246
Amos Plotts Balsam	6,278
Rocky Face	6,031
Double Spring Mountain	6,380
Richland Balsam	6,540
Chimney Peak	6,234
Spruce Ridge Top	6,076
Reinhardt Mountain	6,106
Devils Court-house	6,049
Sams Knob	6,130
Cold Mountain	6,000
Mount Hardy	6,102
Jones Knob	6,209
Mount Junaleska	6,225
Rocky Trail	6,488
Water Rock Knob	6,399
Black Mountain	6,275
Shining Rock	6,040
Rough Butt Bald	6,010
Cold Springs Knob	6,010


DRAINAGE BASINS
OF
SOUTHERN APPALACHIAN
MOUNTAINS
Showing gaging stations maintained by
U S Geological Survey
Scale
WEST VIRGINIA
ATLANTA

	Feet.
Black Mountains:	
Blackstocks Knob (northwest chain)	6,386
Potato Top (northwest chain)	6,487
Black Dome (main chain)	6,502
Mount Gibbs (main chain)	6,608
Mount Hallback or Sugarloaf (main chain)	6,432
Mount Mitchell (main chain)	6,711
Balsam Cone (main chain)	6,697
Black Brother (main chain)	6,645
Cattail Peak (main chain)	6,609
Hairy Bear (main chain)	6,622
Deer Mountain (main chain)	6,220
Bowlems Pyramid or Celo (main chain)	6,351
Locust Mountain	6,088
Burnt or Long Mountain	6,238
Clingman Peak	6,611
Yeates Knob or Big Butt	6,001
Potato Knob	6,419
Patton Knob	6,079
Craggy Range:	
Big Craggy	6,106
Bull Head	6,072

The foregoing table shows a total of 64 peaks having elevations of 6,000 feet or higher. There are 288 peaks that exceed in height 5,000 feet, and the number that exceed 4,000 feet is much greater.

GEOLOGY.

For the following brief description of the geology of the region the writer is indebted to Mr. Arthur Keith, of the United States Geological Survey, who has made a careful study of the Southern Appalachians:

"The geologic formations which underlie this mountain district may be divided into four large groups. Each differs widely from the others in age, and has very distinct features of its own. These broad differences have expressed themselves in such major topographic features as the Appalachian Valley, the Appalachian Mountains, and the Piedmont Plateau. These differences are also largely responsible for the principal variations in the character of the surface in the mountain district itself.

"The Appalachian Valley is underlain by a series of limestones, shales, and sandstones, mainly of Silurian and late Cambrian age, forming the youngest of the four groups in this region. Small outliers of these formations are included within the area of the mountains near the border of the Appalachian Valley.

"The second group occupies the northwestern border of the mountain district, chiefly northeast of French Broad River. It consists of a series of quartzites, conglomerates, and shales of Lower Cambrian age. A second large area of these rocks occupies the Blue Ridge and adjacent territory nearly in the center of this district.

"The third group is of Cambrian age. It occupies the northwest border of the mountain mass, corresponding in position to the previous group but developed southwest of French Broad River in the Smoky and the Unaka mountains. The group consists of conglomerates, graywackes, sandstones, schists, and slates, and is called the Ocoee group. This and the preceding two groups were composed of the waste from older rocks, which was deposited under water. The thickness of the strata is approximately the same in the Ocoee group and the formations of the Appalachian Valley. The Lower Cambrian quartzites and shales of the second group have only from one-fourth to one-third of the thickness of either of the preceding groups.

"The fourth group is much the largest of all, both in actual bulk and in area. It consists in the main of formations of the Archean, or oldest known age. The different rocks include several kinds of granite, diorite, mica- and hornblende-gneiss, and various schists. A large number of these were of igneous origin, but the original nature of many of the gneisses and schists is unknown. Formations also included in this group are the ancient volcanic rocks. These are developed most prominently in connection with the Cambrian quartzites in the northeastern part of the mountain district.

"Much of the surface of the Appalachian Mountains is exceedingly ancient. During the later geologic periods it has been subjected to the various natural agencies of destruction, and has been worn down according as the rocks presented at the surface were susceptible to these influences. The materials composing these formations are attacked in varying degrees by solution and by chemical processes connected with atmospheric and underground water. Certain minerals—for instance, carbonate of lime—are readily dissolved by natural waters, and the rock in wasting away leaves behind only the less soluble portions in the form of clay. To this capability is directly due the reduction of the great valley below the level of the mountain mass. Other minerals—for instance, feldspar—are in part dissolved and in part chemically altered and decomposed by natural waters, so that the coherence of the rock which contains them is largely destroyed. Two groups in this region have a large proportion of feldspar in their make-up, and their surfaces have been gradually lowered by its breaking down. These are the Ocoee group and the Archean group. A third mineral, quartz, is comparatively little changed by solution or chemical action near the surface. Formations made up in large part of this mineral retain their altitudes most persistently, and are usually the last to be reduced. This composition is most pronounced in the Lower Cambrian group, but is shared also by the Ocoee group and the Archean group. Although the thickness of the Lower Cambrian quartzites is so much less than that of the other groups, their resistance to solution has caused them to remain upheld in very high ridges and peaks. To this are due the cliffs of the Chilhowee, Camp

ESCARPMENT OF THE BLUE RIDGE AT BLOWING ROCK, N. C.

Creek, and Iron mountains, and the rugged crags of Grandfather. In the case of the Ocoee and Archean groups their immense thickness and the amount of quartz which they contain have maintained the greatest elevations presented in this region. Of this the mighty domes of the Smokies, the Balsams, and the Roan, and the lofty peaks of the Blacks are witnesses."

RIVERS.

The region is well watered. From it several of the largest rivers of the country receive their supply. The main divide of the river systems is the Blue Ridge. This chain, which enters the State of North Carolina in Alleghany County, extends southwest between Wilkes and Ashe counties and through Watauga County. At Grandfather Mountain, which is at the junction of Watauga, Mitchell, and Caldwell counties, the chain turns more to the south, following the boundaries between Mitchell and Caldwell counties and between McDowell, Yancey, and Buncombe counties, reaching the State line in Macon County. In this ridge and its spurs, cross ridges, and foothills many of the rivers of the Southeastern States have their origin. A view of an escarpment of the Blue Ridge at Blowing Rock, N. C., near Grandfather Mountain, is shown in Pl. III. The States of Virginia, North Carolina, South Carolina, Georgia, Alabama, Tennessee, and West Virginia are partially watered by rivers rising in mountains near the North Carolina and Tennessee State line. One of the principal upper tributaries of the Ohio (the Kanawha) and one of the largest feeders of the Mississippi (the Tennessee) head in the same mountains, and the region may justly be termed one of the chief watersheds of the United States. The drainage basins of the largest rivers are shown in Pl. II.

Flowing into the Atlantic are the Yadkin, Catawba, Broad, Saluda, and Chatooga; into the Gulf are the Chattahoochee and the Coosa. New River flows to the north and enters the Great Kanawha, whose waters finally reach the Mississippi through the Ohio River. Into the Mississippi flow the waters of the Tennessee and its large tributaries—the Holston, the Nolichucky, and the French Broad. From the western slopes of the Blue Ridge flow the headwaters of the great Tennessee river system. This drainage basin has an area of about 1,500 square miles and a length of 300 miles in North Carolina, and a fall of about 1,000 feet between its source and the North Carolina and Tennessee State line. The Cheoah, the Nantahala, the Oconalufty, and the Tuckasegee, all large streams with a width of from 50 to 100 yards, join their waters to the Tennessee, and after receiving them the latter river flows through the Great Smoky Mountains in a narrow and rocky gorge. The Hiwassee joins it in Tennessee.

All of the large streams that flow to the west have the same general

characteristics, i. e., heavy, precipitous falls in the first portion of their courses, then long even flows, with but little fall, across the broad plateaus, finally cutting through the mountain ranges on the border line of North Carolina and Tennessee, where they have rapid and precipitous falls, in some cases more than 1,000 feet in a few miles.

After leaving the State of North Carolina the Tennessee flows in a northwesterly direction for about 300 miles, through the State of Tennessee, being joined by the Holston and the Nolichucky, tributaries which carry as much water as the parent stream. The Holston receives its southern branches from this same mountain region. The Watauga, one of the chief tributaries of the Holston, rises in the center of the mountain district around Grandfather Mountain, and flows in a northwesterly direction through Watauga County, with the high, steep slopes of the mountain sides on either hand, and with frequent falls of a few feet over its rocky bed. After flowing through the Iron Mountains in a rocky gorge and entering Tennessee the Watauga is joined by Roan and Elk creeks, which have drainage areas with the same characteristics as its own. After the junction of these three streams the river flows through Carter and Washington counties, receiving tributaries on either side, the chief of which are Doe River, Buffalo Creek, and Stony Creek. About 20 miles southwest of Bristol the Watauga joins the South Fork of the Holston, and farther down, near Kingsport, the two forks of the Holston unite, forming one of the chief rivers of the State of Tennessee. Near Knoxville the Holston is joined by Nolichucky River, a stream but little smaller than itself, which derives its headwaters a few miles south of the source of the Watauga.

The Nolichucky is formed by the junction of the North Toe, the South Toe, and Caney River, all of which rise in the high mountains of Mitchell and Yancey counties, on the western border of North Carolina. The headwaters of the North Toe are separated from those of Elk Creek, of the Watauga drainage, by a narrow ridge. The North Toe flows to the southwest until its junction with the South Toe, which rises in the Black Mountains, after which it flows in a westerly direction and is joined by Caney River, which also rises in the Black Mountains but flows through a comparatively flat and open valley, draining a large part of Yancey County. After the junction with Caney River the stream is known as the Nolichucky, and flows to the west for 200 miles through the State of Tennessee, receiving numerous tributaries, the chief of which are Lick Creek and French Broad and Pigeon rivers.

The French Broad rises in the Blue Ridge, at the State line between North Carolina and South Carolina, flows in a northwesterly direction, at first with considerable fall, then enters the broad plateau, and with sluggish, even flow continues its course westward until it breaks through the Bald Mountains. Numerous tributaries are received on either side, all of which in their lower courses have the

characteristics of rivers of the plains. The fall of the French Broad from Brevard to Asheville, a distance of 50 miles, is 2.7 feet per mile.

On the north side of Grandfather Mountain are the headwaters of the South Fork of New River. This is the only stream in this region that flows northward. It drains about half of Watauga and Ashe counties, and flows through narrow valleys with steep mountain slopes on either side. After passing into Virginia it is joined by the North Fork of New River, and flows for 100 miles through that State, finally entering West Virginia, where it empties into the Great Kanawha, adding its waters to the Ohio.

From the southern slopes of Grandfather Mountain and the ridge between the towns of Grandfather and Blowing Rock flow the headwaters of the Yadkin. For the first few miles the stream is small and the fall very great, being through a rough and wooded country; but soon the river reaches the vast plateau known as the Piedmont Plain, and its valley opens out into a broad and fertile area, with numerous branches on either side, those from the south, which rise in the Brushy Mountains, being small, while those from the north, which rise in the Blue Ridge, are streams with large flow and considerable fall. The many tributaries add large volumes of water to the Yadkin, and as it flows to the east its discharge increases rapidly, until by the time the South Carolina boundary line is reached it has become one of the largest rivers of the Southeastern States. It flows for 130 miles through the State of South Carolina under the name of Pedee River.

The many springs on the southern slope of Grandfather Mountain join to form John River and Mulberry and Wilson creeks, which unite about 20 miles to the south and finally add their waters to Catawba River. The Catawba rises in the Black Mountains and flows east, descending from the high mountain sides to the level of the Piedmont Plain in frequent leaps of from 5 to 10 feet, and in one or two cases with vertical falls of 100 feet. From Oldfort, in McDowell County, it flows through the heart of the Piedmont Plain, receiving large tributaries from the north, notably North Fork, Linville River, Upper Creek, John River, and Lower Creek, all of which rise on the eastern slopes of the Blue Ridge, two of the chief tributaries, Linville and John, receiving their headwaters from the springs on the slopes of Grandfather Mountain. The river flows to the east, entering Alexander County, where it turns to the south and crosses the South Carolina boundary, after which it is known as the Wateree.

There are two rivers in this region which differ somewhat in their general characteristics from the streams described, viz, the Broad and the Saluda. Broad River is formed by the junction of the main Broad, the Green, the First Broad, and the Second Broad, and receives its headwaters from the slopes of South Mountain and the Blue Ridge. The tributaries, however, soon reach the flat, open plain, and uniting near the State line enter South Carolina near the western border of York County. Farther to the southwest Saluda River receives the

run-off from the Blue Ridge and flows for almost its entire length through South Carolina. Tugaloo River, which flows into the Savannah; Oconee River, one of the chief streams of Georgia and a tributary of the Altamaha; and the Chattahoochee, which waters in part the States of Georgia, Alabama, and Florida, also rise in the Blue Ridge.

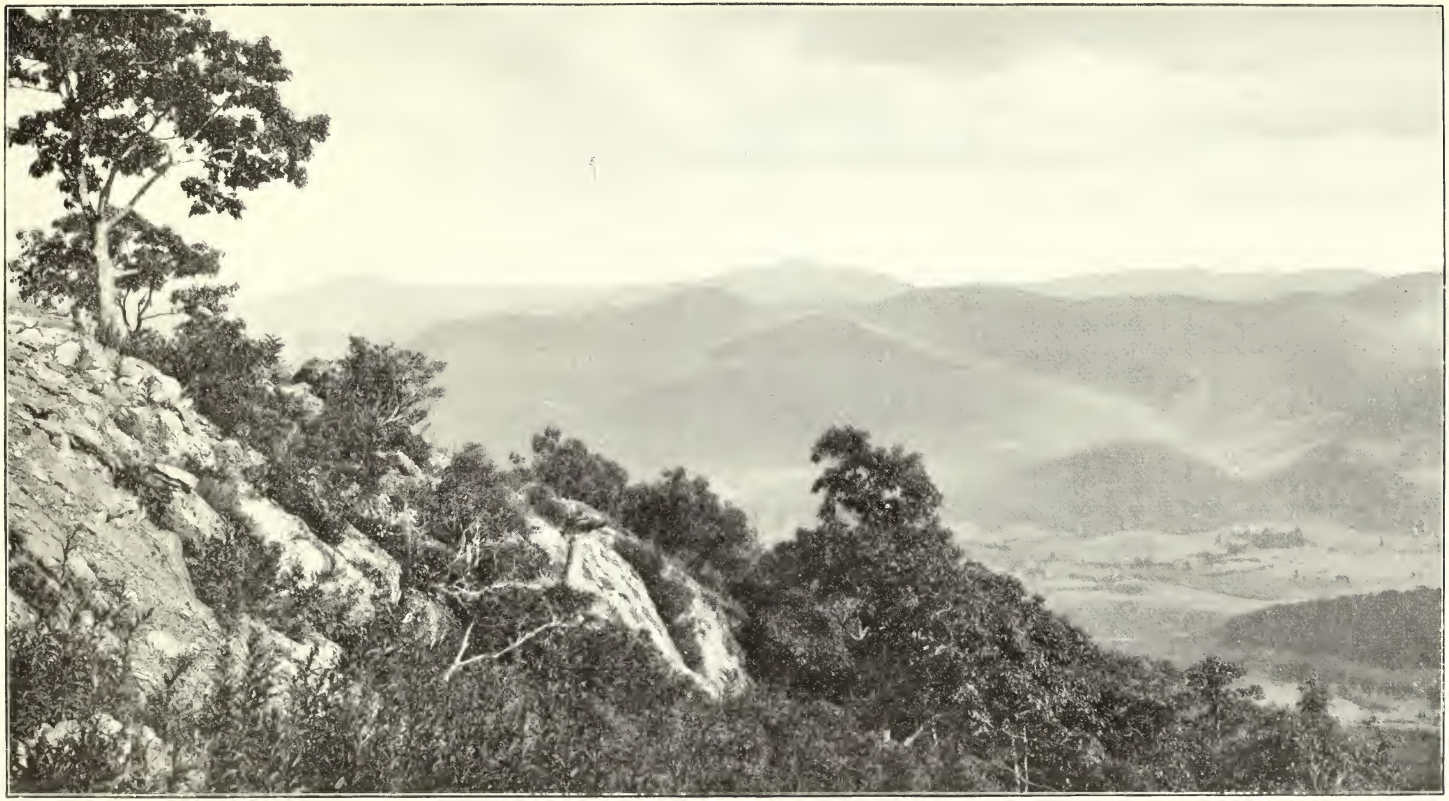
SCENERY.

The scenery of the Southern Appalachian region is the grandest in the Eastern States. While in height the mountains can hardly be compared with the Rockies or the Alps, they far outstrip in height, massiveness, and extent the mountains of the Northeastern States. As one ascends Roan Mountain or Grandfather Mountain or passes through Hickory Nut Gap he is strongly reminded of the scenery of Switzerland, and might well imagine that he was on the Rigi or the Pilatus.

The mountains and valleys are covered with a luxuriant growth of forest trees, making one continuous bank of green from the bases to the summits of the highest peaks. (See Pl. IV.) With tireless energy the rivers have cut their ways through the massive ranges and formed stupendous gorges with bare, rocky walls almost vertical and hundreds of feet in height. These gorges, which confine the wandering streams, present views of rare grandeur and wonderful beauty. The charms of the Linville (see Pl. XXXVIII, Part II), the Cranberry, and the Watauga can not fail to arouse the wonder and admiration of all who visit them. Among the mountains and adjoining elevated plateaus there are a number of places where people seek rest and recreation during the hot months of the year. The visitors, however, are largely from the Southern States, and after spending a summer in these mountains the writer can but marvel that they have been so long overlooked by the people of the Eastern States as an ideal place to enjoy beautiful scenery and exhilarating mountain air. It can be accounted for only by the fact that so little has been known regarding the region, and that it is, unfortunately, rather difficult of access, there being few railroads except those used for lumbering, and the highways being execrable. These drawbacks, however, are rapidly disappearing, and the region would well repay a visit from the tourist or the seeker for health.

In general the mountain views are made up of a billowy succession of ridges (shown in Pl. V), the deep green of the mountains melting into the blue of the sky in the distance, while nearer at hand more subdued shades of green prevail, which in the valleys below merge into the soft, ripe yellows of the grain fields, with here and there a bare cliff or an area of red soil which stands out in sharp contrast. From the Unakas and to the north and west, where lies the beautiful Valley of East Tennessee, the views are of a different character. There the inequalities of surface are almost lost, and for miles the eye rests on a great plain dotted with light-colored cultivated areas and with green forest masses. Among the Unakas many balds occur, of which

TYPICAL FOREST-COVERED MOUNTAIN SIDE.



RICHLAND VALLEY FROM JUNALESKA MOUNTAIN, NORTH CAROLINA.

Whitetop is one of the most conspicuous and those of the Roan the most extensive and beautiful, consisting, as they do, of three or four peaks extending along the top of the mountain in a chain about 6 miles long. Dr. Mitchell many years ago said of Roan Mountain: "It is the most beautiful, and will best repay the labor of ascending it, of all our high mountains. With the exception of a body of rocks looking like the ruins of an old castle, near its southwestern extremity, the top of the Roan may be described as a vast meadow without a tree to obstruct the prospect, where a person may gallop his horse for a mile or two, with Carolina at his feet on one side, and Tennessee at the other, and a green ocean of mountains rise in tremendous billows immediately around him." Some of the highest peaks, however, are not bald, but are covered with a dark and dense growth of balsam and other evergreens. It is from a somber vegetation of this kind that the Black Mountains derive their name.

From Mount Mitchell a view into six States can be had. Although that mountain is the highest peak east of the Rockies, the views from it are not so fine nor so extensive as can be obtained from other mountains of less elevation, for the reason that it is surrounded by peaks with altitudes little less than its own, while Roan Mountain and Grandfather Mountain tower far above their surroundings, and from them magnificent views can be obtained in all directions.

Grandfather Mountain (shown in Pls. VI and VII) is probably the most massive of the Southern Appalachians, and is the culmination of the Blue Ridge. The scenery from it is unsurpassed. For many miles range after range of mountains spread out like the waves of the ocean, with opalescent clouds hanging down in the valleys below. In spring and summer there is the glint of the sunshine on the moist green of the leaves. In autumn the somber green of the balsam and spruce crowning the summits rises above the scarlet and golden glories of the foliage of the hard-wood trees, while in winter the great peaks lie cold and white, bare and forbidding. At every turn some new and beautiful thing is offered. Below the peaks myriad little brawling crystal streams dash in fleecy white over the ledges and around the bowlders that obstruct their courses (see Pl. VIII), or loiter in still pools where the rainbow trout lurk, while still lower are the green valleys hemmed in by the great mountains. On the slopes of Grandfather Mountain, from near the summit to the base, rise innumerable springs of pure, cold water, which uniting form rivulets that flow over rocky precipices and are finally joined into one of the several rivers which flow from its base. The mountain is covered with a heavy forest growth which has not yet known the woodman's ax. Nearly the whole of it, as well as its neighbor, Grandmother Mountain, is owned by the Linville Improvement Company, which controls 16,000 acres of the region, largely covered with forests, and, fortunately, lumbering is not their design. The company has laid out a town site in the valley of Linville River, at the foot of Grandfather Mountain, and intends to sell small tracts to

those who desire summer homes in the mountain region. In order that the springs which give rise to the streams on Grandfather Mountain may not be disturbed, 1,400 acres have been set aside as a public park, under five commissioners, one of whom is the State geologist and another the commissioner of agriculture of North Carolina.

The general contour of the mountains in the Southern Appalachian region is gentle, with smoothly rounded outlines (see Pl. IX), although occasionally sharp peaks are seen and here and there immense precipices are brought into view, especially in the southern portion of the region, as at Whiteside Mountain, one side of which presents a sheer face of naked rock 1,800 feet in height. (See Pl. X.)

CLIMATE.

As has been stated, the Blue Ridge may be considered the great water divide. The mountain region lies to the north and west, while on the east is the Piedmont Plain. The effect of the increased altitude upon the climate is apparent. The high plateau may be said to have cooler summers and more severe winters than the lower lands adjacent, the air is drier and more salubrious, the summer months are remarkably pleasant, the temperature varying somewhat with the altitude, but never too cold for comfort on even the highest mountain peaks. By choosing the proper locality one can obtain an average temperature corresponding to that of northern New England or to the warmer temperatures of the South Atlantic States. The mean annual temperature varies from nearly 60° F. at Salisbury, east of the mountains, to 49° F. at Linville, the latter being about the mean annual temperature of Boston and Chicago. On the mountain slopes the mean annual temperature is still lower. The seasonal temperatures of the mountain region are approximately as follows: Spring, 56°; summer, 73°; autumn, 57°; and winter, 40°. The following table gives the average monthly temperature, the mean annual temperature, and the seasonal temperatures as observed at the Weather Bureau stations in the mountain region:

Temperature observations in Southern Appalachian Mountains during 1900.

Station.	Average monthly temperature.												Mean annual temperature.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
	Deg.	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*	*Deg.*
Biltmore	36.1	34.3	44.9	56.2	63.9	70.8	74.6	74.8	69.9	59.8	47.5	39.4	56.0
Charlotte	41.4	39.5	48.1	59.6	69.0	74.8	79.4	81.9	76.4	65.2	52.0	42.6	60.8
Henrietta	41.0	39.5	50.0	60.0	68.3	74.6	79.9	81.5	76.0	64.8	52.4	43.1	60.9
Hendersonville	36.6	34.6	45.1	54.4	62.4	70.2	73.4	75.4	70.4	62.6	50.0	40.5	56.3
Highlands	32.8	30.6	38.4	51.0	58.4	64.1	67.5	68.1	[a]63.6	56.2	45.3	35.8	51.0
Horse Cove	38.4	35.5	43.6	56.0	62.8	66.6	71.6	74.4	69.4	60.4	49.6	40.6	55.7
Linville	30.3	29.0	36.8	48.0	55.6	64.5	67.2	67.6	63.1	54.3	43.6	34.0	49.5
Morganton	------	------	------	------	------	73.8	79.0	80.0	74.0	62.1	50.9	41.4	------
Mount Airy	37.0	35.6	42.6	55.8	62.4	70.0	76.6	77.6	71.7	61.9	48.7	38.8	56.6
Marion	38.8	36.2	46.8	57.8	66.6	72.8	78.2	80.1	75.2	63.3	51.2	41.5	59.0
Marshall	33.8	34.6	43.2	54.6	64.2	72.0	75.8	76.5	[b]69.6	61.2	------	------	------
Waynesville	35.2	36.1	43.6	52.6	61.0	68.5	71.8	71.4	67.2	58.4	44.0	37.5	53.9

[a] Record for three days missing. [b] Record for six days missing.

GRANDFATHER MOUNTAIN, NORTH CAROLINA.

CENTER, GRANDFATHER MOUNTAIN, NORTH CAROLINA (HIGH PEAK IN BACKGROUND), FROM PIXIE.

Temperature observations in Southern Appalachian Mountains, etc.—Continued.

Station.	Seasonal temperatures.				Latitude.	Longitude.	Elevation.	Length of record.
	Spring.	Summer.	Autumn.	Winter.				
	Deg.	*Deg.*	*Deg.*	*Deg.*	° ′	° ′	*Feet.*	*Years.*
Biltmore	55.0	73.4	59.0	36.6				2
Charlotte	58.9	78.7	64.5	41.2	35 13	80 51	808	22
Henrietta	59.4	78.7	64.4	41.2				
Hendersonville	54.0	73.0	61.0	37.2				1
Highlands	49.3	66.6	55.9	33.1	35 5	83 25	3,817	15
Horse Cove	54.1	70.9	59.8	38.2	35 0	83 6	2,800	6
Linville	46.8	66.4	53.7	31.1	36 5	81 51	3,800	4
Morganton		77.6	62.3		35 45	81 44	1,135	9
Mount Airy	53.6	74.7	60.8	37.1	36 30	80 40	1,048	10
Marion	57.1	77.0	63.2	38.8	35 30	82 5	1,425	5
Marshall	54.0	74.8						
Waynesville	52.4	70.6	56.5	36.3	35 29	82 58	2,756	4

Highlands, the highest station, is 3,817 feet in elevation, while several of the mountain ranges and peaks reach altitudes of from 5,000 to 6,000 feet, and their temperatures are lower than those given in the table. The following table gives the temperature extremes at a number of observation stations:

Temperature extremes in Southern Appalachian region.

Station.	Elevations.	Length of record.	Highest monthly mean.		Lowest monthly mean.		Highest observed.		Lowest observed.	
			Temperature.	Date.	Temperature.	Date.	Temperature.	Date.	Temperature.	Date.
	Feet.	*Yrs*	*Deg.*		*Deg.*		*Deg.*		*Deg.*	
Asheville	2,250	23	74.8	July, 1879	27.2	Jan., 1893	95	Sept. 15, 1897	[a]— 9	Jan. 16, 1893 Feb. 8, 1895
Chapel Hill	500	41	82.2	July, 1893	28.4	Jan., 1857	105	Aug. 10, 1892	— 1	Jan. 16, 1893
Greensboro	843	15	82.6	do	32.3	Dec., 1876	101	Aug. 10, 1896	6	Jan. 28, 1897
Highlands	3,817	15	70.9	July, 1878	24.4	Jan., 1893	86	June —, 1891	—17	Feb. 8, 1895
Horse Cove	2,800	6	74.4	July, 1893	28.5	do	93	Sept. 15, 1897	—13	Do.
Lenoir	1,186	26	77.7	July, 1877	27.3	do	95	July 18, 1887	—16	Dec. —, 1880
Morganton	1,135	10	80.0	July, 1868	26.4	do	100	Sept. 16, 1897	— 1	Jan. 16, 1893
Mount Airy	1,048	10	77.1	July, 1872	26.2	do	98	Sept. 28, 1891	—15	Do.
Mount Pleasant	650	12	79.1	Aug., 1896	29.9	do	98	June 29, 1889	— 4	Jan. 21, 1893
Murphy	1,614	12	76.9	July, 1878	28.5	Dec., 1876				
Salisbury	760	13	82.0	July, 1893	33.0	Jan., 1893	102	Aug. 10, 1896	5	Feb. 21, 1896

[a] Minus sign indicates temperature below zero.

PRECIPITATION.

The annual rainfall is copious, larger than anywhere else in the United States except on the northwestern coast, in Oregon and Washington. As might be supposed, it varies considerably in different parts of the high regions. The warm, moist winds from the east and south are deflected upward by the Blue Ridge, causing a cooling and consequent precipitation. In this way the yearly rainfall is greatly increased on the slopes of those mountains. At Highlands, in Macon County, the annual normal precipitation is about 72 inches and at Horse Cove about 73 inches. West of the Blue Ridge the annual rain-

fall is much less in the valley bottoms between the mountain ranges. For instance, a long record at Asheville gives a normal rainfall of about 42 inches, the smallest of any record of the mountain region. The normal at Waynesville, in Haywood County, is 46 inches. The average precipitation of the whole region may be considered to be approximately 53 inches. The following table gives the monthly, annual, and seasonal precipitation for 1900:

Precipitation in Southern Appalachian region during 1900.

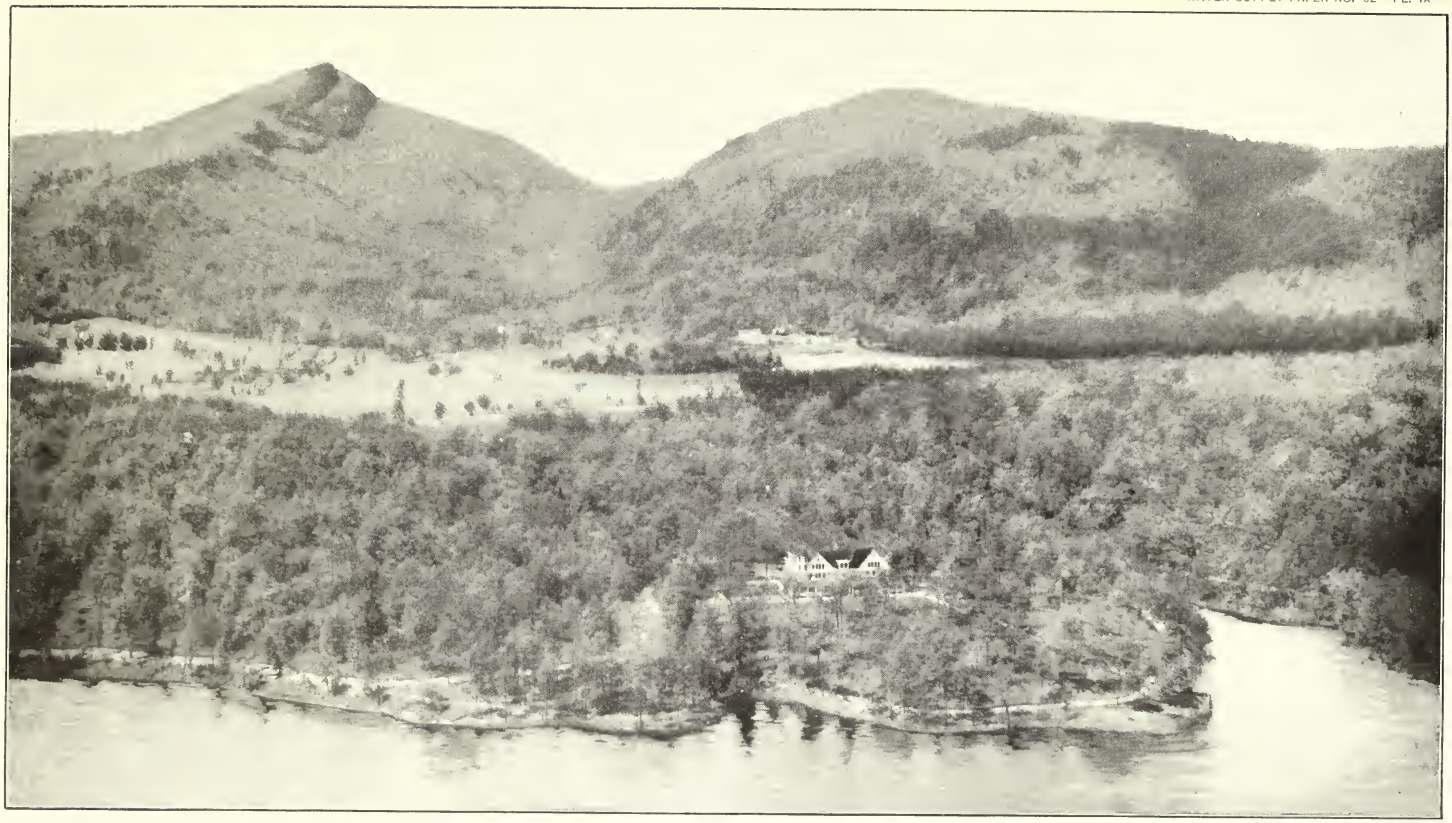
Station.	Monthly precipitation.												Mean annual.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Abshers	3.35	7.50	4.92	4.89	2.93	9.28	7.43	4.14	5.46	8.73	5.15	3.35	67.13
Asheville	2.26	4.67	5.53	4.18	0.99	8.11	1.99	2.54	3.39	2.92	4.62	3.46	44.66
Biltmore	2.41	6.90	2.87	3.31	1.37	7.91	2.10	0.52	2.51	3.67	3.34	3.80	40.71
Bryson	2.85	7.72	7.33	4.67	1.21	6.31	2.88	4.48	3.02	2.87	4.80	4.76	52.90
Charlotte	2.15	5.25	5.28	5.32	2.11	7.31	3.55	3.05	0.73	3.41	3.85	4.33	46.34
Cherryville	3.31	7.01	5.65	7.55	3.34	6.39	2.25	2.61	2.01	2.29	4.04	4.80	51.25
Flatrock	.....	13.24	5.06	.....	.....	.....	.....	.....	.....	8.17	3.87	3.90	.....
Hendersonville	3.94	10.10	5.76	8.06	3.83	8.79	5.75	1.53	3.80	4.10	3.47	4.98	64.11
Henrietta	3.09	10.69	5.29	6.77	2.92	6.99	2.79	1.45	1.05	4.15	5.27	5.10	55.56
Highlands	5.82	13.84	7.10	10.20	1.67	19.29	8.04	1.95	4.99	6.00	5.03	7.53	91.46
Horse Cove	4.28	12.98	7.10	8.83	2.28	19.92	9.43	3.36	6.74	8.63	5.94	6.67	96.16
Linville	2.63	5.34	7.60	5.51	2.17	7.07	3.99	3.70	4.42	13.40	4.47	3.95	64.25
Maria	2.13	5.17	4.06	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Marion	3.59	9.22	6.65	9.70	1.96	10.50	3.52	2.70	3.48	9.69	4.04	4.74	69.79
Marshall	1.26	4.07	3.69	2.62	1.46	8.33	1.49	2.69	3.63	3.51	2.25	3.09	38.09
Mount Airy	2.35	4.00	[a]3.50	[a]3.67	1.02	8.56	3.52	2.50	4.12	4.04	3.10	3.38	43.76
Mount Pleasant	2.11	6.68	3.07	4.34	2.53	4.87	.....	.....	.....	.....	.....	.....	.....
Morganton	.....	.....	.....	.....	.....	5.97	2.65	1.15	2.10	3.20	2.26	4.40	.....
Mocksville	3.40	4.38	6.18	4.68	3.13	.....	2.88	2.07	2.08	3.04	3.31	3.32	.....
Murphy	3.55	6.45	7.07	4.83	2.19	8.87	4.04	2.78	3.19	5.19	5.22	5.45	58.83
Salisbury	3.22	4.52	5.02	4.98	4.12	4.81	3.52	1.79	1.60	1.90	2.10	6.35	43.93
Settle	2.82	5.34	3.30	4.30	2.40	5.57	2.43	3.95	3.56	2.99	3.08	4.51	44.25
Waynesville	2.38	6.97	6.00	6.41	1.01	7.64	3.55	2.25	2.49	2.12	3.57	4.08	48.47

Station.	Seasonal precipitation.				Latitude.	Longitude.	Elevation.	Length of record.
	Spring.	Summer.	Autumn.	Winter.				
	In.	*In.*	*In.*	*In.*	° ′	° ′	*Feet.*	*Years.*
Abshers	12.74	20.85	19.34	14.20	.....	.....	.....	.....
Asheville	10.70	12.64	10.93	10.39	35 37	82 30	2,250	22
Biltmore	7.55	10.53	9.52	13.11	.....	.....	2,150	2
Bryson	13.21	13 67	10.69	15.33	35 27	83 23	2,000	10
Charlotte	12.71	13.91	7.99	11.73	35 13	80 51	808	22
Cherryville	16.54	11.25	8.34	15.12	.....	.....	.....	.....
Flatrock	.....	.....	.....	.....	35 15	82 25	2,214	6
Hendersonville	17.65	16.07	11.37	19.02	.....	.....	2,167	1
Henrietta	14.98	11.23	10.47	18.88	.....	.....	.....	.....
Highlands	18.97	29.28	16.02	27.19	35 5	83 25	3,817	15
Horse Cove	18.21	32.71	21.31	23.93	35 0	83 6	2,800	6
Linville	15.28	14.76	22.29	11.92	36 5	81 51	3,800	4
Maria	.....	.....	.....	.....	.....	.....	.....	.....
Marion	18.31	16.72	17.21	17.55	.....	.....	1,425	5
Marshall	7.77	12.51	9.39	8.42	.....	.....	.....	.....
Mount Airy	8.19	14.58	11.26	9.73	36 30	80 40	1,048	10
Mount Pleasant	9.94	.....	.....	.....	35 28	80 28	650	12
Morganton	.....	9.77	7.56	.....	.....	.....	1,135	9
Mocksville	13.99	.....	8.43	11.10	35 51	80 34	651	4
Murphy	14.09	15.69	13.60	15.45	35 8	84 0	1,614	20
Salisbury	14.12	10.12	5.60	14.09	35 4	80 29	760	13
Settle	10.00	11.95	9.63	12 67	.....	.....	.....	2
Waynesville	13.42	13.44	8.18	13.43	35 29	82 58	2,756	4

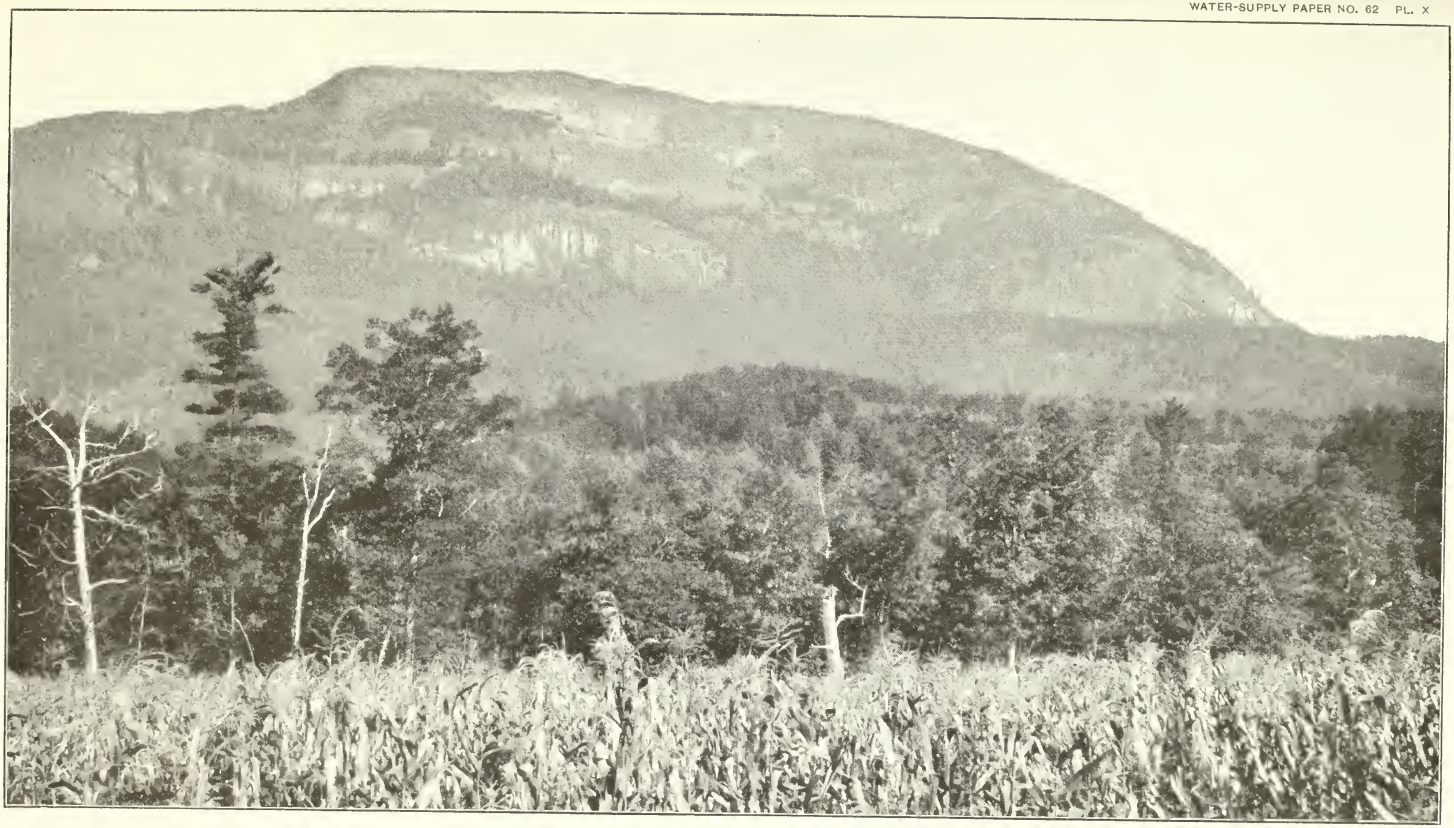
[a] Partly estimated.

Heavy rains occur at short intervals, which with the steep slopes cause rapid increase in the flow of the streams for a day or a few

SKYUKA FALLS, NORTH CAROLINA, A TYPICAL MOUNTAIN WATERFALL



VIEW IN THE SAPPHIRE COUNTRY, NORTH CAROLINA, SHOWING SMOOTHLY-ROUNDED TOPOGRAPHY.



WHITESIDE MOUNTAIN, NORTH CAROLINA.

hours, when the rivers as rapidly fall to their normal stage. Floods are frequently caused by the heavy rains. It is exceedingly difficult, however, to obtain measurements of the extreme high waters, for unless one is near the station at the time the water rises the river falls before he can reach there. A rainfall of 7.39 inches was recorded at Salisbury on June 10, 1883, and 6.01 inches at Highlands on February 8 and 9, 1891.

There is considerable snowfall during the winter months of the year, the average annual snowfall at a few stations being as follows: Asheville, 16 inches; Highlands, 22 inches; Lenoir, 11 inches; and Mount Airy, 12 inches.

The following table gives the greatest and least monthly precipitation:

Table showing greatest and least monthly precipitation in Southern Appalachian region.

Station.	Elevation.	Length of record.	Greatest monthly precipitation.		Least monthly precipitation.		Highest monthly average.	Lowest monthly average.
			Amount.	Date.	Amount.	Date.		
	Feet.	*Years.*	*Inches.*		*Inches.*		*Per cent.*	*Per cent.*
Asheville	2,250	23	[a]11.40	July, 1874	0.21	Oct., 1895	143	74
Charlotte	808	22	11.13	Mar., 1891	0.23	Nov., 1890	126	74
Highlands	3,817	15	20.20	Feb., 1891	0.25	May, 1883	135	79
Horse Cove	2,800	6	17.02	June, 1892	0.62	Oct., 1892	136	38
Lenoir	1,186	26	11.50	May, 1873	0.00	Nov., 1890	133	78
Morganton	1,135	10	11.20	Apr., 1878	0.20	Oct., 1892	129	67
Mount Airy	1,048	10	10.38	July, 1889	0.17	Nov., 1890	147	60
Mount Pleasant	650	12	10.27	Aug., 1887	0.28	Oct., 1892	142	66
Salisbury	760	13	16.14	do	0.13	Nov., 1890	128	67

FORESTS AND LUMBERING.[b]

Nearly the whole of these mountains was once covered with a magnificent growth of timber, which owing to its inaccessibility was long spared the woodman's ax. Now, however, since the forests of the North and the West have been denuded, the lumbering element has turned its attention to the Southern Appalachians, and the vast forests there are rapidly disappearing. Railroads have penetrated the mountains, and mills large and small have been located in the forested areas. One great railroad traverses the heart of the region, with a branch from Asheville through Macon and Cherokee counties. Lines have also been constructed up Doe and Nolichuky rivers, and a number of other lines have been surveyed, some of which will probably be built within a few years. Wherever a railroad is constructed the neighboring timber soon disappears, in consequence of the cheaper transportation. Most of the large mills are steam sawmills, and they are moved deeper into the forests as the supply of timber in their immediate vicinity is exhausted, the railroads being extended to them. Near the rivers the logs are splashed down the streams to the timber

[a] There is record of a greater amount than this, but it is not considered quite trustworthy.

[b] During the summer and fall of 1900 extensive investigations of the forests of the Southern Appalachian region were made by the United States Bureau of Forestry, Gifford Pinchot, forester.

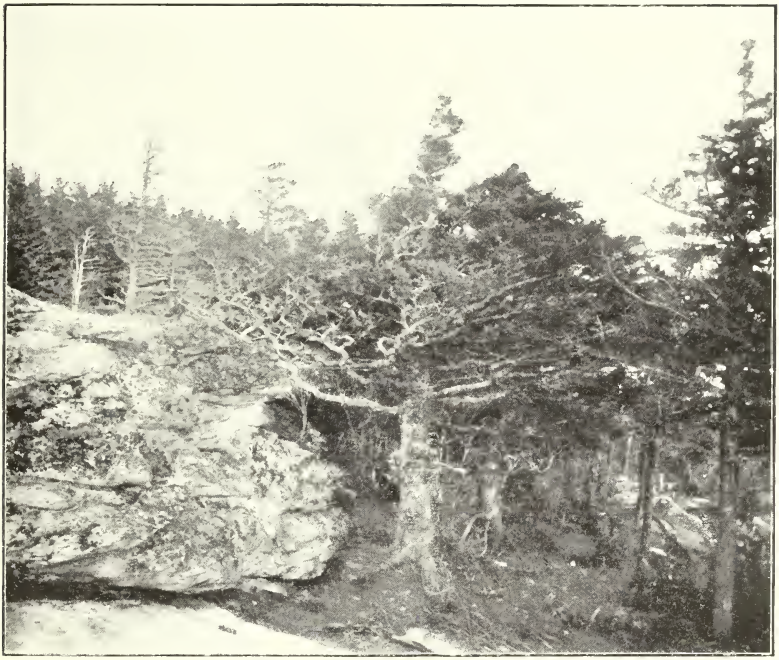
pens of the mills below, thus saving the cost of railroad transportation or long hauls over rough and steep roads. Splash dams are constructed which hold back the water in dry seasons and float the logs over the rocky beds of the streams.

Notwithstanding the inroads that have been made on these forests, nowhere in the United States is there an equal area of land covered with so great a variety of valuable timber. The walnuts, tulips (poplars), and oaks grow to almost incredible size (see Pl. XI). In many localities white pine occurs in large tracts, growing to great heights (see Pl. XII) and furnishing as fine lumber as any of the pine forests of the country. Near the summits of all of the higher mountains the only growth is the balsam. Most of these trees are exposed to the cold and wind, and for that reason are small and twisted (see Pl. XIII, *A*), but where protected they grow to large size, especially in the Craggy and the Smoky mountains. Numerous varieties of rhododendrons grow on the slopes of many of the mountains, forming an almost impenetrable jungle. During the flowering season these present a most beautiful appearance, being often a mass of blossoms stretching as far as the eye can reach in every direction. Grandfather Mountain is particularly rich in this growth (see Pl. XIII, *B*), the chief species being *Rhododendron maximum*, *Rhododendron catawbiense*, and *Rhododendron vaseyi*.

Although the region still has the finest hard-wood forests in the country, the large tracts of wild cherry and black walnut which once flourished have entirely disappeared, and the mills are now sawing cheaper lumbers, such as oak, white pine, ash, and poplar. Not many years ago the supply of walnut was so abundant that old mountaineers tell of splitting rails from walnut logs and of burning or allowing to rot the walnut stumps which to-day would bring immense sums from veneering factories. The unfortunate feature of this lumbering is that there is no discrimination in the cutting. All of the trees, large and small, are felled, and if found not suitable for immediate use they are allowed to rot on the ground. In many places the lumber companies are recutting areas which have once been gone over, and are denuding them of even the smallest trees. Some of the companies saw anything that will make a plank. In the case of the bark gatherers the wastefulness is particularly deplorable. These men fell the trees—chiefly chestnut-oak and hemlock—for the bark, and after stripping them make no attempt to use the timber. Every year hundreds of cords of bark are hauled from these mountains, and each load means that some giant of the forest lies useless on its native soil. Near the railroads it is profitable to saw the timber and haul it to the station, but the natives find that they can strip the trees and haul the bark much farther than they can afford to haul the timber. It is a mournful sight to see these immense trees lying where felled, of no use to anybody, simply marking the wanton wastefulness of man.

POPLAR FOREST.

PINE FOREST.



A. WIND-DWARFED BALSAM FIR ON GRANDFATHER MOUNTAIN, NORTH CAROLINA.

B. RHODODENDRON THICKET, NEAR GRANDFATHER MOUNTAIN.

Lumbering on a large scale has been carried on for only a few years, but in addition to the large steam mills, which are moved deeper into the forest as the timber in their vicinity is exhausted, every little creek now has one or two small water-power sawmills cutting from 500 to 5,000 feet a day. Dry kilns are built and planers are put in so that the mills can turn out finished lumber. Although by the old methods fearful inroads were made on the forests, so thorough is the denudation by the new mills that it will not take them many years to exhaust all of the timber that is worth sawing.

The four largest lumber plants operating in this section are the Watauga Lumber Company, on Watauga River; the Empire Company, in the Shady Valley; the Ritter Company, at Pineola, on Linville River; and a new company with main yards at Huntsdale, Tenn., on the Nolichucky.

The Watauga Lumber Company owns almost all of the timber in the Watauga Valley. They have built five splash dams for the purpose of floating logs down to their mill. Two of these dams are on the main river, one at Shulls Mill and the other just above the mouth of Beaverdam Creek. On Beaverdam Creek there is a splash dam about 2 miles from the mouth, and during the summer of 1900 the company removed much of the timber from the lower part of the Beaverdam Valley. About 6 miles up Laurel Creek they have another splash dam, and are now cutting the timber in that region. The fifth dam is on Elk Creek, just below the big falls. They have not commenced lumbering there yet, but they own all of the timber. At Shulls Mill the company has built a tramroad up in the mountains to haul their logs to the river. They cut only the white pine and the poplar, because of the distance the logs have to be splashed. They now have thousands of logs all along the river from Shulls Mill to their mill below Elizabethton.

The Empire Company started work in the Shady Valley during the summer of 1900. They have put up a large mill and timber pen on Beaverdam Creek, and later will put in a dry kiln. The mill is to be run by steam. The Holston Valley Railroad is being built from Abingdon, Va., for the purpose of getting this lumber out. The railroad follows down the South Fork of Holston River to the mouth of the Laurel Fork, then up the Laurel Fork and Beaverdam Creek. This is considered one of the finest timber regions in the mountain section, consisting mostly of white pine and spruce, with a very little hard wood, mostly chestnut. The land being very fertile, the trees have grown to great size, being nearly 100 feet to the first limb. Up to the present time the timber in this valley has been almost untouched, on account of the long haul over the mountains to a railroad.

The Ritter Company, at Pineola, has had its mill in operation about a year. It is run by steam, and has a capacity of 50,000 feet a day. Their timber pen is on Linville River, and the logs are brought to it

by a narrow-gage railroad, which also carries the timber to Johnson City, Tenn., by way of Cranberry, N. C. The tract of this company, which contains some very fine white pine, extends from Pineola to Linville Falls, on both sides of Linville River, and includes most of the timber on Jonas Ridge.

The Ohio River and Charleston Railroad has been constructed from Johnson City, Tenn., up the valley of Nolichucky River as far as the mouth of Caney River, and a large lumber yard and shipping point have been established at Huntsdale, Tenn. A number of steam sawmills have also been built on the slopes of the Black Mountains. These mills are temporary structures and will be moved from point to point to avoid long hauls of the logs. The lumber is hauled to Huntsdale for shipment. Huntsdale has sprung up on the banks of the Nolichucky like a western mining town, and is not yet on maps of the region. The owners expect to extend the railroad very soon. It is said that they have bought 1,000,000 trees and are still increasing their purchases.

Several other companies are doing considerable lumbering. A company in Bristol has built a railroad to transport timber from the mountains south of Bristol across the South Fork of Holston River.

The many wood-working establishments on the Tennessee side of the mountains use considerable lumber, and close to the railroad on that side much soft wood is cut for the pulp mills in Bristol and other places.

Despite the great inroads on the forests in this region, many large areas have not been touched. The timber near the tops of all of the higher and steeper ridges still remains. This is particularly noticeable in the area between the South Fork of Holston River and the Watauga, where, except in the Shady Valley, which is now being cleared, all the timber that could easily be reached is gone, and only that at the tops of the steepest mountains remains. Three especially large areas, however, have not been cut, namely, Grandfather Mountain, the Black Mountains, and the long strip of land on both sides of Linville River. Grandfather Mountain is owned by the Linville Improvement Company, and it is not likely that they will permit any lumbering. The variety of trees in this area is greater than in the other regions, being hard woods near the base of the mountain and fir near the summit. The Black Mountains have escaped the lumberman only because of the difficulty of removing the logs and getting the lumber to market. Since the completion of the Ohio River and Charlestown Railroad to Huntsdale, however, several mills have started work around the bases of those mountains, and it will not be long before the timber is cut well up the sides.

On both sides of Linville River, from just below Linville to Beech Bottom, there is a very large strip of land containing exceptionally fine timber which has not been cleared of even the most valuable

trees. The upper end of this strip, however, is owned by the Ritter Company, and they are clearing the area, as already mentioned. Their tract extends from just below Linville nearly to Linville Falls, and contains some especially fine white pine. The next strip, extending from a half mile above the falls to 3½ miles below them on each side of the river, and containing 51,000 acres, is owned by the Morganton Improvement Company. The next lower area, running down the river to Beech Bottom, belongs to the Cheever Improvement Company. The two latter tracts are very rich in white pine, poplar, ash, oak, hemlock, spruce, and the linn or linden.

Three railroads have been surveyed to run through this district—one from Bristol to Lincolnton, another from Cooks Gap to Lenoir, and the third from Collettsville, on John River, to Cranberry, to connect with the narrow-gage railroad running to Johnson City, Tenn. If these railroads are built the timber in the vicinity will soon be cut, leaving the ground bare, as it is along the other roads.

The unfortunate feature of the lumbering is that the ground is completely stripped of trees and then is left without cultivation. The slopes are often too steep for successful farming, and in many places the top soil is washed off and the hillsides become more or less gullied by the water rushing down the mountains.

Great as has been the havoc wrought by the lumberman, his part in the forest destruction has been small when compared with that of the clearing of the land for agricultural purposes and with forest fires. Too often the farmer, instead of trying to improve the soil in the valley, makes additional clearings on the mountain sides. Owing to the steepness of the slopes, the productiveness of the hillside fields is short lived. After the trees have been girdled and the underbrush destroyed the land can be planted in corn for one or two years, then in grain for a year, and then in grass for one or two years, after which it can be used as pasture land for a year or two, until, with increasing barrenness, the grass gives place to weeds and the weeds in turn to gullies.

Forest fires have been one of the great curses in the Southern Appalachians, as elsewhere in the country. They were of frequent occurrence in the days of Indian occupation. Thus they have preceded the lumberman, have accompanied him, and have followed in his wake, and their work has been rendered far more destructive by the lumberman leaving brush scattered among the remaining growth in such a way that in the burning it has fed the fires.

In some regions fires have entirely destroyed the forests, especially where the soil was thin and composed largely of humus. The burning of the humus has resulted in the remaining soil being soon washed away, leaving the trees standing on the bare surface of rock to dry out and die. In other places fires have destroyed the undergrowth and the larger trees have been burned near the roots in such a way

as to cause their destruction. Repeated fires in the undergrowth have exterminated the grasses and other forage plants over large areas, so that instead of improving the pasturage, which is frequently the object of starting the fires, the result has been in the course of years its almost total destruction.

That the burning of the humus and undergrowth in the forests seriously affects the flow of the streams anyone who has been in a forest during a heavy rain storm will admit. In the virgin forest the raindrops are caught by the underbrush and pass downward through the humus into the less porous soil and the rock fissures beneath, to reappear weeks and months later in the form of numberless springs. But where the underbrush and humus have been burned away much less water soaks into the soil, most of it flowing down the surface with a velocity varying with the slope, washing the soil into small furrows and gullies, causing the rapid accumulation of the water into brooks, and resulting in floods in the larger streams in the valleys below.

In New England and many of the Northern States the numerous lakes and glacial deposits of sand and gravel spread out over the hills and valleys of that region serve as a storehouse for the water and materially assist the forest cover in preserving uniformity in the flow of the streams. Indeed, they would accomplish much in that direction were the forest cover entirely removed. But in the Southern Appalachian region there are no lakes and no glacial gravels and sands, hence the water storage depends entirely upon the forests and the soil.

SOIL AND VEGETATION.

Besides the actual reduction of the earth's surface according as the rocks differ in susceptibility to atmospheric agencies, the region has been profoundly affected by the soils which the rocks have produced, for on the soils the character and amount of the vegetation are largely dependent.

The soil is naturally deep and fairly fertile even to the mountain tops, while the valleys, which have been cleared, are remarkable for their fertility. In the valley of each little mountain stream can be seen the small cabins of the mountaineers, who cultivate the narrow tracts of land close to the river and often attempt agriculture on the steep slopes of the mountain sides. Pl. XIV gives views of two characteristic mountain homes. In these houses the natives live on from generation to generation, seemingly without desire for change or betterment. When the eldest son is married he is given a portion of his father's land, which he in turn attempts to clear and cultivate, managing to eke out a scanty existence, and being, like his forefathers, well satisfied with his surroundings and his condition in life. Fruits and vegetables grow abundantly and to large size, and would no doubt be cultivated much more were it not for the lack of means of transportation. The entire region is well adapted to stock raising, which is

A.

B.

TYPICAL MOUNTAIN HOMES.

SPRING ON BLACK MOUNTAINS, SHOWING DENSE PLANT GROWTH.

one of the chief industries. Years ago General Clingman wrote: "Horses and horned cattle are usually driven out into the mountains about the first of April and brought back in November. Within six weeks after they have thus been put into the range they become fat and sleek. There are, however, on the top and along the sides of the higher mountains evergreen and winter grasses on which horses and horned cattle live well through the entire winter. Such animals are often foaled and reared there until fit for market, without even seeing a cultivated plantation." This custom of turning the stock loose on the mountains still continues; and in recent years considerable attention has been given to fine stock breeding.

Many varieties of shrubs and flowering plants abound, and the region should prove a Mecca for botanists. Pl. XV (a view on the Black Mountains) will give an idea of the great variety of ferns and plants with which the mountain slopes are covered. In the foreground is one of the cool springs for which the region is noted.

According to Mr. Arthur Keith, of the U. S. Geological Survey, "the moist atmosphere is conducive to the rapid decay of the rocks, which break up chiefly under the attack of rain, frost, the roots of the trees, the underground waters, and organic acids. At first decay works in along the various partings, resulting in the loosening of large masses, which gradually become smaller, until finally nothing is left of them except clay and the more obdurate bits of rock. The rocks reach the surface over only very small patches, while in places the disintegration attains a depth as great as 50 feet. On sloping surfaces the loose material is maintained in its place solely by friction. When this is lessened or overcome from any cause, the residual matter, be it clay or rock fragments, slides down the slope until the friction is again sufficient to retain it in one position. Thus are formed immense deposits washed down from steep slopes and accumulated in the hollows and flatter places. This material gradually works its way downhill, as it is pushed along by the freezing of the water, or is rendered more unstable as the water transforms it into mud. Eventually it finds its way into the streams and is carried by slow stages into the sea.

"The chief agent which checks this process of removal is the forest cover, even though the penetrating roots and the acids due to vegetation induce rock decomposition. These same roots, however, hold the loose material in place and check its tendency to slide downhill. With this assistance loose soils are upheld on slopes fully double those which they could maintain unaided. Besides this direct hindrance to the waste of slopes by increased friction, the action of the forests is as great in another way. Loose material is washed downhill during rain storms by even the tiniest rivulets.[a] In open fields these gather in a

[a] Pl. XVI, *A*, shows the starting of such a wash in a deforested area and illustrates the way in which this wash is checked by the growth of trees higher on the mountain side. H. A. P.

few minutes, and form deeper and deeper channels with each succeeding storm, finally removing the loose material down to the bare rock. This process is almost prohibited by the network of roots and the cover of leaves, both living and dead, and the water concentrates into rivulets by seeping through the soils so slowly that it carries no sediment. The waters finally drain off in the hollows and small streams whose channels have been fitted by long use to withstand the attacks of rushing water.

"Countless illustrations of this process can be seen during any rain storm. Streams which drain considerable areas of cleared land rise fast and become turbid with mud. Those which drain areas protected by forests rise much more slowly, and by comparison the water could be called clear, except in violent storms. This result is of course most striking at the very headwaters, the little streams rising in the fields and in the woods. The effects of this work are seen in the innumerable gullies which gash fields left to the elements for any time. In fact, unless checked by the most constant attention these gullies soon strip off the soil and clay and ruin the fields.[a] In the forests, on the other hand, one rarely sees a slope of soil not covered with vegetation, and it is only along the immediate banks of the streams that raw slopes of loose material are exposed. In short, in this region of deep residual soils the influence of the forest is paramount. It is a fact well known among the mountaineers that the soils are far more fertile when first cleared from timber than ever again. It is equally well known among the farmers along the river bottoms that the same crops have been planted there with equal success for scores of years. These latter soils, however, are refreshed from time to time by the overflowing waters, which have swept off fertile materials from the steeper slopes above. The natural fertility of the mountain soils is very great, as is abundantly shown by the dense and luxuriant forest growth. The pristine strength of the soil soon wanes in the clearings, however, and there ensues a loss which is permanent for at least a generation. To convince one's self of the existence of this condition it is only necessary to visit the region.

"In addition to the loss inflicted by forest cutting upon the steep slopes themselves great damage also results to the lands lying farther down the streams. The deep clays and underlying rocks form a kind of gigantic sponge which stores up water during its plenty. When the forests are stripped away the waters collect and run off with vastly greater speed, and much evaporates, so that not only is less stored up, but the discharge is more irregular and temporary. Destructive floods result and droughts are wider spread. Thus, viewed from the standpoint either of utility or beauty, these unrivaled forests are the keystone of the arch."

During high floods the rivers carry enormous quantities of sand and

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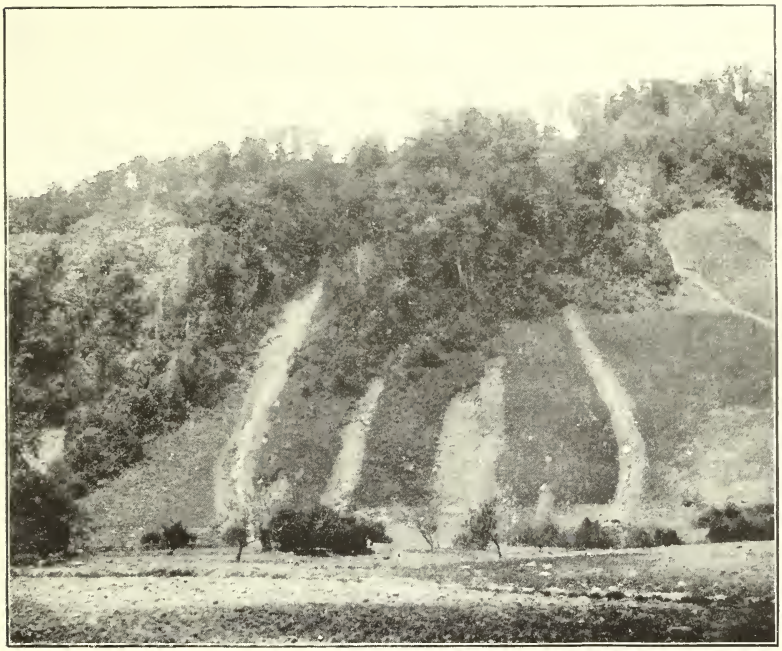
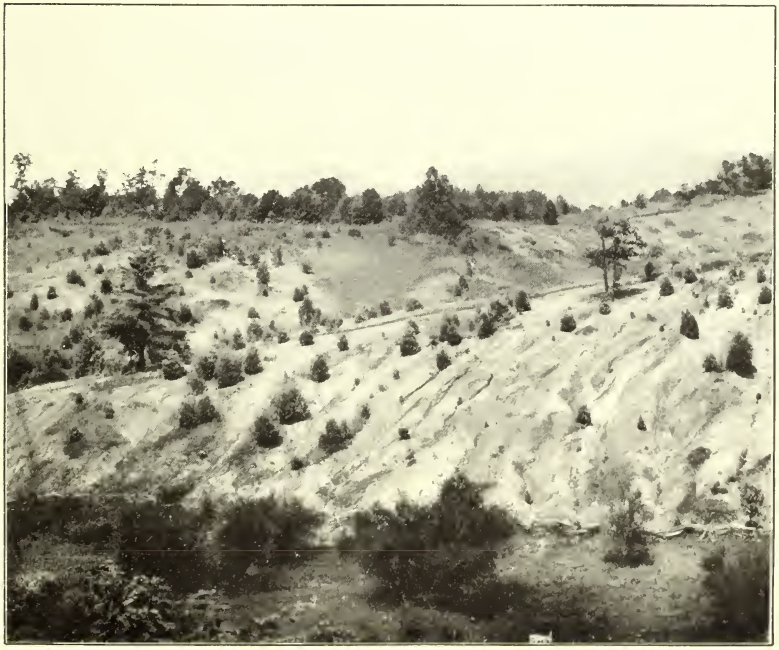
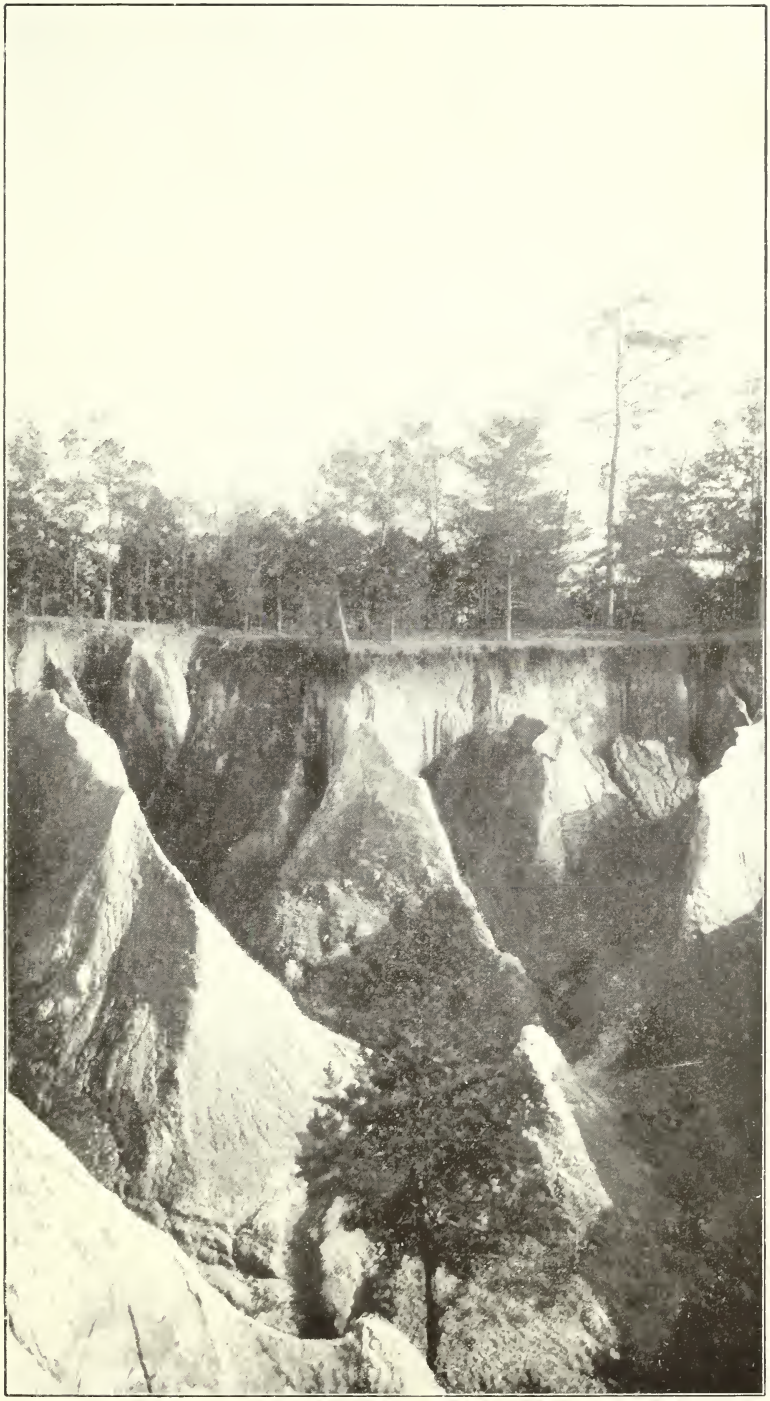
[a] See Pls. XVI, *B*, and XVII. H. A. P.



A. VIEW SHOWING BEGINNING OF WASH ON MOUNTAIN SIDE.



B. VIEW OF DEFORESTED HILLSIDE SHOWING EFFECT OF EROSION.



WATER-WASHED GULLY IN DECOMPOSED GNEISS, McDOWELL COUNTY, N. C.

clay washed from the mountain sides. This material is deposited in great beds upon the cultivated lands along the rivers below (see Pl. XVIII, *A* and *B*), making future tilling impossible and ruining immense areas of arable land.

Inasmuch as the rivers are chiefly dependent upon their headwaters for supply it is impossible to overestimate the importance of preserving the forest cover on the mountain sides.

MINERAL RESOURCES.

No effort will be made to describe in detail the mineral resources of the region. The geological surveys of the various States and of the United States have published considerable literature on that subject, and further studies of it are now being made. Stated briefly, corundum abounds in certain localities. The mica of Yancey and Mitchell counties is widely known as among the best in the world, the deposits being so extensive as to furnish a large part of the world's supply. In a number of counties iron occurs in large quantities, and copper and other minerals have been mined to some extent. In the descriptions of the various drainage areas mention will be made of the more important mineral resources of specific localities.

HIGHWAYS.

The highways of the region are bad, having steep grades and being poorly surfaced. In many localities practically no work is put on the roads, and during certain seasons of the year they become almost impassable to wagons. This is largely due to the neglect of the inhabitants, for in most parts of the mountain districts excellent road materials exist, and with proper care and intelligence the highways could be maintained in good condition at moderate expense. Upon the mountain sides the rain water is allowed to run in the road bed, soon washing out great gullies and exposing the rocks, so that a horse is obliged to pick his way from side to side with great care and the rider to be constantly on the alert to prevent accident. Such a road is shown in Pl. XIX, *A*. The highway from Marion, N. C., to Sprucepine, illustrated in Pl. XX, is a typical mountain road of this region over which a wagon can pass, but with difficulty. In many cases, in order to avoid cutting a road on the slopes of the mountains, the stream bed is used as a highway, although usually exceedingly rough and at the time of high water dangerous to the traveler. Pl. XXI illustrates a road bed which has for years been used as a highway. Farther down the river valleys, where clays are more prevalent, the roads are often exceedingly muddy, it being a common occurrence for the wagons to sink hub deep into the mud. (See Pl. XIX, *B*.) There are a few remarkable exceptions, however, as, for example, the toll road from Linville around the base of Grandfather Mountain to Blow-

ing Rock, known as the Yonahlossee road and shown in Pl. XXII, and the road between Blowing Rock and Boone, both of which are excellent in grade and surface and show what can be done when the materials at hand are used with skill.

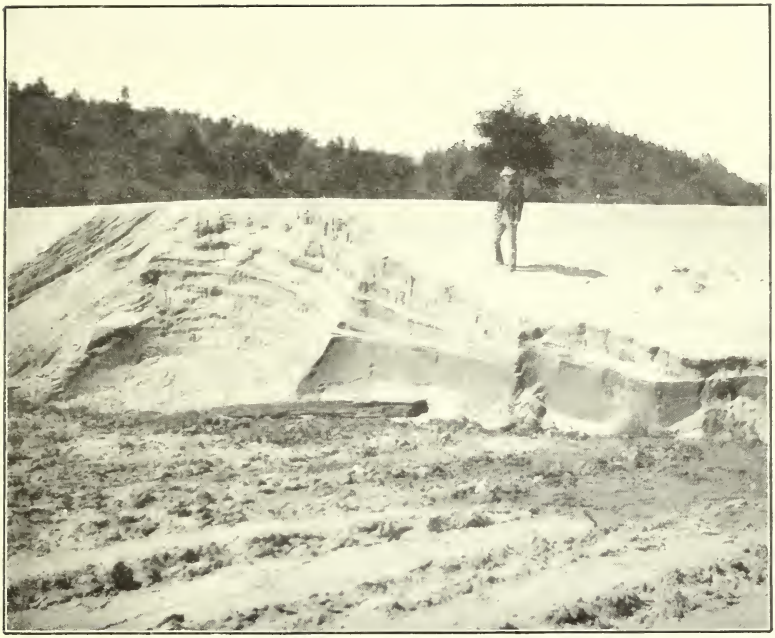
DRAINAGE BASINS.

In the course of the examination of the watersheds and the general investigation of the flow of the streams in the Southern Appalachian region which were carried on during the summer of 1900, many measurements of flow were made on the larger streams and on most of their upper tributaries, the results of which are contained in this report. The small Price meter was used in making measurements. There being few bridges in the region most of the measurements were made by wading. It was therefore impossible to make gagings of many of the streams at the time of high water.

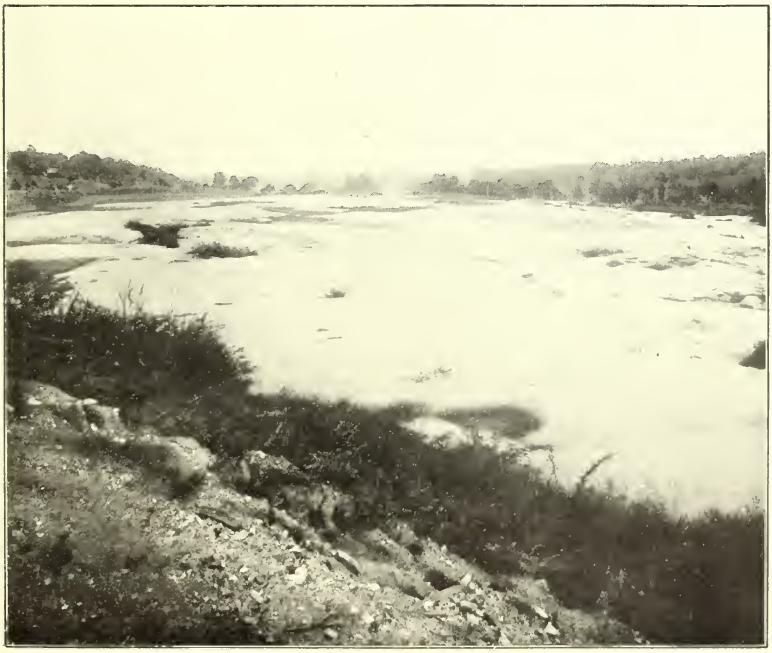
In some respects the season was peculiar. Rain was abundant during June and the streams were moderately high during the early part of the summer. Later, however, very little rain fell, and most of the rivers and their tributaries were at an extremely low stage, as low, in fact, as they have been for a number of years. An effort was made to make more than one measurement at the same point on each stream. When the first measurement was made a bench mark was established, and the relative height of the water surface was measured at each successive gaging. Examinations were also made for high-water marks, and when the annual fluctuations of a stream could be determined they were noted. By means of these data a knowledge of the flow of the streams at various stages and of the relation that exists between the rise of the streams and their discharge can be obtained, though of course the only definite information we have is the discharge at the time of measurement.

On the larger streams gaging stations were established, as is the custom of the Survey, the height of the water surface being read daily on the gage and recorded by a local observer, and the measurements, which were made as often as practicable, being referred to the same gage. With these data a curve was plotted, using the gage readings as ordinates and the stream discharge, in cubic feet per second, as abscissæ. From this curve, the mean of the daily gage readings being known, the approximate daily discharge was interpolated. This method is described in detail in the annual reports of the Survey and in Water-Supply Paper No. 56.

The great difficulty encountered at these stations, which are on mountain streams, was to obtain measurements at the time of high water. After a rain the rivers rise rapidly, and as they fall as quickly, unless a person is near the station the high water will have passed before he can reach the point of measurement.



A. SAND AND CLAY DEPOSIT IN VALLEY.



B. SAND DEPOSITED UPON FARMING LAND BY RIVER FLOOD.

A. WATER-WASHED COUNTRY ROAD IN MITCHELL COUNTY, N. C.

B. UNIMPROVED ROAD IN VALLEY.

The following is a list of the gaging stations established in the basin:

Gaging stations established during 1900 on streams in Southern Appalachian region.

Stream.	Location.	Date established.
		1900.
New River	Oldtown, Va	August 5.
South Fork of New River	New River, N. C	July 29.
North Fork of New River	Weaversford, N. C	Do.
Yadkin River	Siloam, N. C	August 3.
Catawba River	Morganton, N. C	June 19.
John River	do	Do.
Linville River	Bridgewater, N. C	July 3.
Broad River	Dellinger, S. C	August 30.
South Fork of Holston River	Bluff City, Tenn	July 17.
Watauga River	Butler, Tenn	August 11.
Roan Creek	do	Do.
Elk Creek	Lineback, Tenn	August 5.
Nolichucky River	Chucky Valley, Tenn	September 20.
Pigeon River	Newport, Tenn	September 4.
French Broad River	Oldtown, Tenn	Do.

Besides the foregoing stations, which were established during the summer of 1900, the following gaging stations have been maintained for several years upon streams flowing from the Southern Appalachian Mountains:

Regular gaging stations of the Geological Survey on streams flowing from the Southern Appalachian Mountains.

New River at Radford, Va., and at Fayette, W. Va.
James River at or near Glasgow, Buchanan, Cartersville, and Holcomb Rock, Va.
Roanoke River at Roanoke, Va., and at Neal, N. C.
Dan River at South Boston, Va.
Staunton River at Randolph, Va.
Yadkin River at Salisbury and Norwood, N. C.
Catawba River at Catawba, N. C., and at Rockhill, S. C.
Broad River (of the Carolinas) near Alston, S. C.
Saluda River at Waterloo, S. C.
Tallulah River at Tallulah Falls, Ga.
Tugaloo River near Madison, S. C.
Savannah River near Calhoun Falls, S. C., and at Augusta, Ga.
Oconee River near Dublin, Ga.
Chattahoochee River at Oakdale and at West Point, Ga.
Coosawattee River at Carters, Ga.
Oostanaula River at Resaca, Ga.
Coosa River at Rome, Ga., near Riverside, Ala., and at locks Nos. 4 and 5, Alabama.
Toccoa River near Blueridge, Ga.
Nottely River at Ranger, N. C.
Hiwassee River at Charleston and Reliance, Tenn., and at Murphy, N. C.
Tennessee River at Chattanooga and Knoxville, Tenn.
Little Tennessee River at Judson, N. C.
Tuckasegee River at Bryson, N. C.
French Broad River near Asheville, N. C.

These stations cover every stream rising in the Southern Appalachian Mountains. Results of measurements will be found in the annual reports of the Survey.

HOLSTON RIVER.

PHYSICAL FEATURES.

The areas drained by Holston River comprise the basins of the North, South, and Middle forks of that stream, the Watauga, the Nolichucky, and the French Broad, including parts of southwestern Virginia, eastern Tennessee, and western North Carolina. The river is one of the largest of the streams which form the great Tennessee River. It rises along the western slopes of the Blue Ridge, in Smyth and Bland counties, Va., in three forks, known as the North, Middle, and South forks, respectively. The North Fork, from its position, receives no tributaries rising within any of the areas proposed for the projected Appalachian National Park, and for that reason, in view of the very large area necessary to be covered during the field season and the limited time in which to perform the work, it was not investigated. The areas drained by the Middle and South forks were quite thoroughly studied, and many direct instrumental measurements were made of their flow and of the flow of all streams tributary to them whose discharge was sufficiently great to admit of the use of a current meter, the minimum limit being, roughly, a little less than 1 cubic foot per second, depending largely on the form and character of the bed of the stream.

The physical conditions of the drainage basin vary greatly, the character of the country ranging from the gently rolling plain of the South and Middle forks, with its smooth, rounded, and grass-covered hills, to the grandest and mightiest mountain masses to be found east of the Rocky Mountains, such as the Unakas and the Black Mountains, with their numerous peaks rising more than 6,000 feet above sea level, and with steep and rocky slopes still clad in virgin forest. There are wide variations in the soil and in the general geologic conditions and structure, considerable variation in temperature and rainfall, and still wider variations in the character of the streams of the area, which include the brawling mountain torrents fed by perpetual springs, the puny wet-weather streams of the slate country, and the subterranean streams of the limestone regions. The entire area is part of the great Mississippi slope, of which the eastern boundary is formed by the Blue Ridge Mountains, on which all of the streams of this area rise, those of Virginia flowing to the southwest, through the great Valley of East Tennessee, those from North Carolina flowing to the northwest, through the Unakas, in grand and deep gorges and down the valley slopes to their union with the main stream.

The Unaka chain, the most prominent natural feature within the

MOUNTAIN ROAD NEAR SPRUCEPINE, N. C.

area, is a long range, the most massive of the Appalachians, its high crests forming the boundary between North Carolina and Tennessee. It is for the most part one single ridge, but occasionally it spreads out into a series of from two to four parallel ridges. The chain is continuous except that it is intercepted by the deep and rocky cuts of the tributaries of the Holston and the Tennessee. In Virginia it unites with the Blue Ridge. It forms large parts of Johnson, Carter, Washington, Greene, Cocke, and Unicoi counties in Tennessee. In Johnson County the ridges lie in such a manner as to completely encircle the great cove of the county, and in Carter County they nearly inclose the valleys. It has been said that the chain is a belt of parallel ridges, but in most of the Tennessee part of it the ridges are two in number, one being the main axis of the chain, the other lower and lying along the foot of the slope, though generally separated from the main range by long coves. This typical character does not always hold good, however, the greatest departure being in the country to the northeast of French Broad River.

In the northeastern corner of the State, north of Watauga River, in Johnson and Carter counties, the Unakas divide into three distinct ranges separated by wide and beautiful valleys. Seen from some points these ridges appear parallel, but in reality they are convergent toward the north, and near the Virginia line the Holston and the Iron mountains, the most western of the diversions, converge, and farther on, in Virginia, the two ranges unite in the long chain known as the Iron Mountains. The most easterly of these three ranges is the Stone Mountains, a long series of crowded ridges, along the crest of which runs a portion of the State line, extending from south of the Watauga and culminating in the grand and conspicuous summit of Whitetop. The middle range is the Iron Mountains, a long, straight ridge extending through Johnson and Carter counties—a portion of it forming for a long distance the boundary line between those counties—being separated from the Stone Mountains by the valley lands of the former county. Watauga River and Doe River have cut through this range, but it continues to be well defined until the southern part of Carter County is reached, and there it sinks away. South of the Watauga it is separated from the mountains on the east by a long and narrow valley known in its wider portion as Doe River Cove. The last and most westerly of the ridges is the Holston Mountains, which run out abruptly from the other ridges and terminate as abruptly a few miles north of Elizabethton, Tenn. They are separated from the mountains on the east by the curious, very elevated basin called Shady Valley and by the valley of Stony Creek.

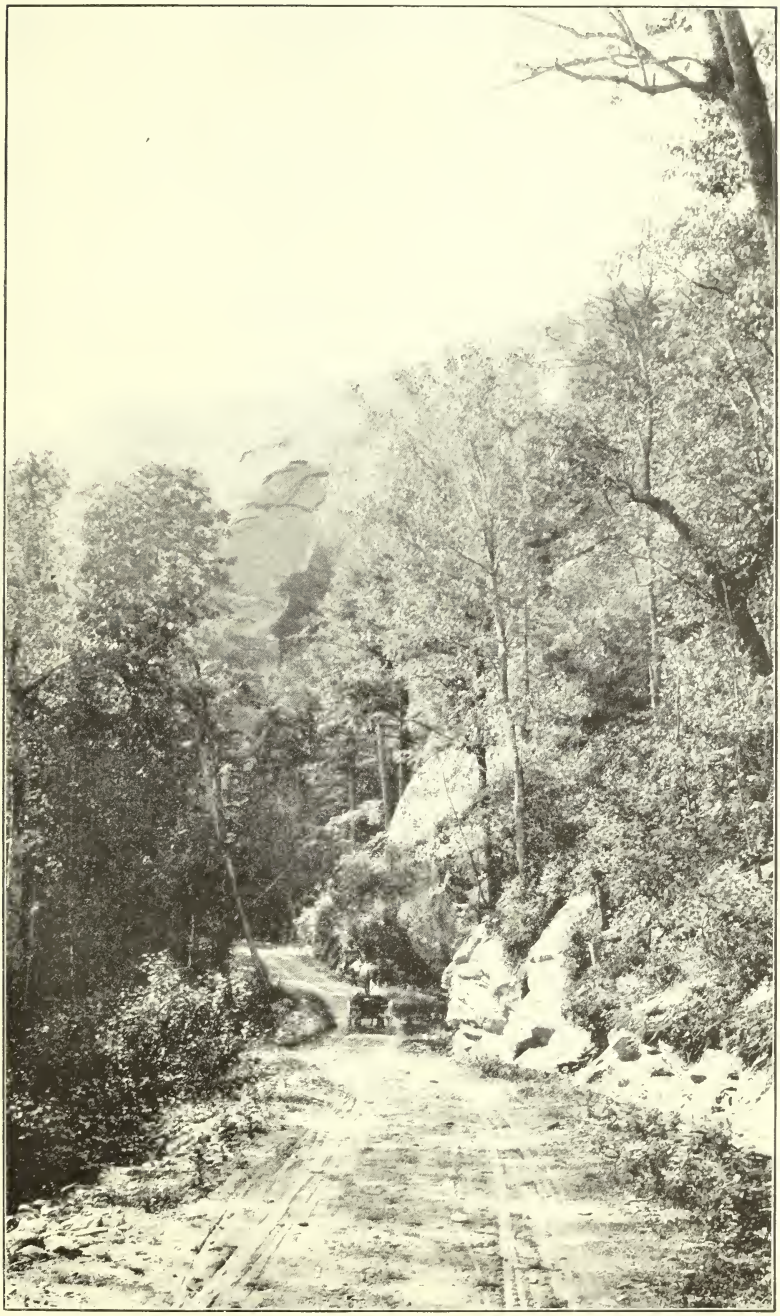
As a rule the Unaka ridges are forest clad. The higher summits, however, are frequently destitute of trees, owing perhaps to the high altitude and the consequent low temperature, but more probably to peculiarities of the soil. Such summits are called balds. Sometimes

they are a mile or more in diameter, and sometimes a chain or succession of them occurs along a ridge, forming a continuous bald for several miles. Roan Mountain is a bald of the latter class, and there are several others like it in the range. The most magnificent views in the mountains are obtained from these peaks.

Lying to the west of the Unakas is the great valley known as the Valley of East Tennessee. This broad and beautiful basin is a southward continuation of the famous Valley of Virginia. In Tennessee it has an extreme width of more than 50 miles. It is drained by the Holston and its tributary streams. The portion of the valley covered in the course of this investigation embraced parts of Sullivan, Carter, Johnson, Washington, Greene, and Cocke counties. The topography is composed largely of a series of parallel ridges, the axis extending in a northeast-southwest direction, making the country very rolling when viewed transversely. One of the most marked peculiarities of the region is the short and narrow ridges of slate which are apparent here and there over the area, sometimes occurring in short chains of slaty knobs. In Washington, Greene, and Cocke counties the valleys partake of the nature of the ridges and are short and broken. There are wide variations in the width of the stream valleys, some being sharp and V shaped, others several miles in width and very beautiful and fertile. One of the largest of the valleys is in Johnson County—Johnson County Cove, as it is sometimes called. Its form and position can be seen by reference to almost any map of the area. Below Mountain City it is divided lengthwise by Doe Mountain, an isolated sandstone ridge, but the parts are united again in the valley of the Watauga, which is said to have a larger area than any other valley of similar elevation in the State. It narrows to a point a short distance from the Virginia line, and is entirely inclosed by mountains, the Stone Mountains being on the east and south and the Iron Mountains on the northwest.

Lying between the Holston and the Iron mountains, just before they unite in Virginia, is the elevated basin called Shady Valley, also situated in Johnson County, and being much higher than the great valley just described, but having a much more limited area. The elevation is so great that the flora partakes of the character of that found in the northern regions of Canada. Iron of good quality and very fine white pine and spruce are found here. This valley is more fully described on pages 65 to 66, in the description of the area drained by Beaverdam Creek.

The rivers of the Valley of East Tennessee are wide and shallow, the waters clear and beautiful, and the tributaries numerous. There are two general directions of flow, the tributaries flowing to the northwest or the southeast and the main streams flowing to the southwest. The valley floor throughout is very level to gently rolling, composed of small and rounded hills with gentle, grass-covered slopes, leaving



YONAHLOSSEE ROAD, AROUND THE BASE OF GRANDFATHER MOUNTAIN, NORTH CAROLINA.

broad areas of level meadows or bottom land between them and dotted over with small tracts of hard-wood trees. From this general level the transverse ridges as a rule rise gently, although they are sometimes very rough and rugged and are almost entirely forested.

The area drained by Holston River in Virginia is entirely within the limits of Washington and Smyth counties, being the southeastern half of each county. The extreme southern and southeastern parts of the area are covered by the northward extension of the great Unaka chain known as the Iron Mountains. The extreme eastern part is covered by the slopes of the Blue Ridge and its outliers, the Pond and the Brushy mountains. On the north it is closed in by the slopes of Walker Mountain, a long ridge which separates the watersheds of the North and South forks of the stream. The general characteristics of these mountain areas are similar to those previously described for the Unaka chain in Tennessee, except that the peaks rise to less heights and are completely wooded. The geologic structure is, however, different, many of the mountains being capped with sandstone, the prevailing rock of the valley floor being limestone. The valley itself is much more broken, and in its upper part contains a much smaller portion of cleared land than the areas farther to the south, the natural consequence of the changed topography. However, the strip of level land bordering the South Fork on the south, the entire area between the South and Middle forks, except the slopes of the Pond and the Brushy mountains, and the area to the north of the Middle Fork as far as Walker Mountain are well situated for agricultural and stock-raising pursuits, are almost entirely cleared, and are in a high state of cultivation, being held at a very high valuation.

The part of the watershed in North Carolina, being the areas drained by the Watauga, Nolichucky, and French Broad rivers, is included in the counties of Watauga, Yancey, Mitchell, Madison, Buncombe, Henderson, and Transylvania, and is described at length in connection with the drainage basins of those rivers. The last four counties comprise the watershed of the French Broad. The first three counties—Watauga, Yancey, and Mitchell—occupy the entire width of the transmontane plateau lying between the western slopes of the Blue Ridge and the Unakas, and their surface is a bewildering confusion of mountain chains and spurs extending in every direction, without order or plan, and inclosing short and narrow valleys and inconsiderable areas of cleared land, except along some of the larger streams.

One of the distinguishing characteristics of the whole basin drained by Holston River is the occurrence of small closed basins or sinks, which are found in great numbers on the low divides between the various tributary watersheds. They are so numerous, in fact, that in many localities it seems impossible that any of the rainfall over areas of a square mile or more can find its way into the streams. Certainly

there are no channels visible, and in many cases water was seen standing in pools from 50 to 100 feet in diameter, indicating that there is no subterranean passage through which the water finds its way to the streams. Other sinks are dry, except after heavy rains. In some instances the farmers have rendered the bottoms of these natural basins impervious, and the collected water is used for cattle.

Springs are numerous over all the basin, ranging in size from a discharge of several cubic feet per second to less than a gallon per minute. Many of the smaller streams seem to be fed entirely from this source. In this connection may be noted the fact that a number of streams which at some point in their course sink below the surface of the ground, after flowing there for distances varying from a few yards to a half mile or more reappear on the surface. Some streams were noted which while discharging no water into the main stream carried a considerable quantity a short distance above their mouths, the water sinking gradually into the earth as the river was approached. It is said that the Middle Fork loses a quantity of water in this way, and from the character of the country rock this seems by no means improbable.

RAINFALL.

Little definite information can be given regarding the annual rainfall in this basin, but it is well known that throughout the region there is no lack of moisture, showers frequently falling on the mountains when there is not a cloud over the valley. The rainfall in the valley to the west is between 40 and 45 inches per annum, and that on the mountains is certainly greater. Throughout all the area covered by the investigation there is a lack of records whereby the rainfall can be even approximately determined, most of the records obtainable being very fragmentary. Those at Knoxville best represent the average condition prevailing over the valley, though the Chattanooga records may be of service in determining the average rainfall. The maximum precipitation recorded at Knoxville is 73.8 inches per annum, which is 146 per cent of the mean, and up to 1896 the minimum was 37.4 inches, or 74 per cent of the mean. At Chattanooga the maximum is 68.1 inches per annum, or 126 per cent of the mean, and the minimum is 37.2 inches, or 69 per cent of the mean. It may be stated that the variation between the maximum and minimum rainfall is at least as great as this throughout the region, the precipitation in dry years being somewhat less than 50 per cent of the mean.

Droughts are rare and as a rule of short duration. The most notable one occurred in the summer and autumn of 1900, when throughout the entire country, both in the valleys and on the mountains, the drought was very severe and long continued, producing the lowest known stage of flow in all of the streams. During the winter the higher summits are almost entirely covered with snow

AGRICULTURE.

As might be expected from the comparatively scanty population and the inadequate transportation facilities, agriculture and stock raising are the principal pursuits. In the valley of Holston River, where the country is comparatively level, there are many fine farms, which are held at a high valuation, and the community seems extremely prosperous. Although the areas drained by the Watauga and the Nolichucky are rough and mountainous, yet the lower slopes afford a fine cattle range, and the valleys are sufficiently extensive to produce the necessities of life for the inhabitants.

MINERALS.

The mining possibilities are very large, although little has been done to develop this source of wealth. In the localities where mines have been opened the work seems to have been carried on in a very spasmodic way. Iron ore of great purity is found in abundance in many places, and has been mined to a considerable extent at some localities, the ore being reduced at the furnaces at Bristol, Johnson City, Embreville, and Cranberry within the basin, or shipped to Pulaski and near-by points outside of it. Copper, lead, zinc, fluor-spar, gypsum, gold, salt, barytes, mica, corundum, and gem stones all occur in quantity, and some have been mined at large profit.

LUMBER.

The lumber interests also are of great importance, the area containing many large tracts of fine timber, from which several large sawmills draw their supplies, while small portable mills are found over all the area. A large amount of tan bark is stripped near the railroads, the stocks being sometimes worked into cord wood, but more often allowed to rot where they fall.

TRANSPORTATION.

The transportation facilities over the greater part of the area are pitifully inadequate. The Norfolk and Western Railroad skirts the northern edge of the basin of Holston River proper, the Knoxville branch of the Southern Railway follows along the French Broad, there is a narrow-gage road from Johnson City to Cranberry, a small standard-gage road has been constructed from Bristol to Butler and is now being extended up the valley of Roan Creek toward Mountain City, while another road is being built from Abingdon to Damascus, from which place it will extend up Beaverdam Creek and into the Shady Valley, and the Ohio River and Charleston Railroad has recently been extended along the Nolichucky as far as the mouth of Caney River. In by far the greater part of the area, however, the only means of

transportation is by wagons drawn over the mountain roads, which are generally very rough and steep.

SOUTH FORK OF HOLSTON RIVER.

PHYSICAL FEATURES.

The South Fork of Holston River rises on the western slopes of the Blue Ridge, in Smyth County, Va., between the slopes of the Brushy Mountains on the north and the Iron Mountains on the south. It is formed by the junction, in a broad stretch of valley land, of Slemp and Cressy creeks, and flowing in a general southwesterly direction is joined by the Middle Fork about 6 miles southeast of Abingdon, Va. The stream below this junction and until the junction with the North Fork is still known as the South Fork. Below the latter junction it is known as Holston River.

The headwaters of the South Fork are at an altitude of about 2,800 feet, those of the Middle Fork at an altitude of about 2,900 feet, the elevation at the junction being about 1,800 feet. The altitude at the junction of Slemp and Cressy creeks is about 2,575 feet. The distance between the latter junction and the junction with the Middle Fork is about 29 miles in a straight line, and the average slope of the country about 27 feet to the mile. Following the course of the river, however, this distance is about 36 miles, and the average fall between 21 and 22 feet to the mile.

Although the basin is, broadly speaking, a plateau, it is not to be inferred that it has not some very sharply marked mountain ridges. The axes of these ridges extend in a northeast-southwest direction, approximately parallel to the course of the principal streams, and the buttressing spurs of the Iron and the Stone mountains serrate the southern edge with a series of high and jagged ridges. Away from these, however, the country is composed of a series of low, broad swells and wide, flat valleys, all of the slopes being gentle and covered with grass not unlike the famous blue grass of Kentucky. The soil seems very fertile, and good crops of corn, wheat, oats, and hay are produced.

For convenience in describing this large area, the country has been divided as follows: (1) Area drained by the South Fork below junction with the Middle Fork; (2) area drained by the South Fork above junction with the Middle Fork; and (3) area between the South and Middle forks. The area drained by the Middle Fork is described on pages 69 to 77.

AREA DRAINED BY THE SOUTH FORK BELOW THE JUNCTION WITH THE MIDDLE FORK.

This area lies entirely within the eastern half of Sullivan County, Tenn., and to the north and east of Bluff City, the western limit of

the investigation. Throughout the basin occur many small closed basins or sinks, ranging in size from perhaps 50 feet in diameter to areas covering several acres. In many of them water was seen standing to a depth of several feet. Others bore traces of having recently contained water, while others were well drained. These basins are not indicated on any map of the area, and computations of run-off will be much complicated by them, as the amount of water kept back from the streams is a totally unknown quantity. The country rock is a limestone, much jointed and laminated in places, very massive in others, and these sinks are characteristic of that formation. Ledges of slate are numerous. The limestone is gray to black in color, and strikes to the northeast, the dip being frequently as great as 85 degrees. It is of very good quality, being suitable for quarrying into building stone, and a considerable quantity is used locally, none, however, being quarried for shipment, so far as could be learned. Perhaps the the most important use to which this stone is put is for flux at the various blast furnaces. Small amounts are also burned into lime, which is used in the local building operations or is applied to the land. A small quantity is also used as a road material, but this quantity is very small indeed, for little attention is paid to the roads, which as a rule are poorly graded and ill kept. The soil is in places a red clay impervious to water, but seems for the most part to be a gray, yellow, or brownish loam, and is very fertile.

The country on the south side of the river near Bluff City is preeminently suited to agriculture and to stock raising, being made up of a series of very low and broad ridges and small swells or hills rising from 25 to 30 feet above the level of the valleys between, all forming the surface of a plateau elevated 200 feet or more above the river level. The hillside slopes are gentle, ranging from 5 to 10 degrees, and there are large areas of level land. The general impression of the country when viewed from a distance is that of a plain, but at closer range it is seen to be very gently rolling. By far the greater portion (about 80 per cent) of the land is cleared and either cultivated in corn or wheat or sodded in grass, the areas of each being about equal. The forest growth occurs in small and segregated areas, too small to have much effect on the run-off from the surface. The character of the growth varies, being in some parts almost exclusively pine, while in others and over the larger part of the area oak and chestnut are the predominant trees. Many other varieties, however, are found in abundance, and occasionally the finer cabinet woods, such as walnut, curly maple, and curly birch. As the main stream is approached the country becomes much rougher, the small stream valleys being more deeply carved and the hillside slopes steeper. The descent from the broad upland plateau to the river plain several hundred feet below is very steep.

Ascending the river the uplands for several miles above Bluff City

are similar to those described, except that possibly the proportion of cleared land is slightly less; but it is estimated to be about 75 per cent of the area, and at least half of it is in grass. Throughout this part of its course the river runs in a channel carved through the soft limestone country rock and into the harder and more resistant slates, producing a very rough bed, the slate being much jointed and laminated and projecting in jagged ridges across the course of the stream; but the fall seems well distributed, there being little noticeable concentration at any point.

Going up the river the portion of cleared land seems to gradually decrease, until near the mouth of Weaver Creek it has diminished to one-half or less. This is a consequence of the greatly changed topography, the plateau character of the uplands having been largely lost, sharp and rugged forest-covered hills having taken the place of the small, round, grassy knolls and wide, level bottoms seen farther down the stream. Near the mouth of Weaver Creek the mountains close in on the river, and from that point to and above the mouth of Morrills Creek all of the basin lying to the south of the stream is very rough. There is no arable land along the river, and the hills are wooded to the top.

On the south side of the stream the country draining into the river below the junction with the Middle Fork is composed of the basins of Jacobs Creek and Denton Valley Creek. Near the river the country is more gently rolling than farther downstream, and as a consequence is more largely cleared, but of the whole area drained by Jacobs Creek probably only about 10 per cent is cleared, most of it near the mouth. A short distance up the stream the country becomes broken and rough and is largely in woodland. For about 3 miles above the mouth of Denton Valley Creek a considerable portion—possibly one-third—of the land is cleared, being largely devoted to grazing. The hillside slopes vary from 15 to 30 degrees. These slopes show a great deal of exposed limestone. Above this 3-mile stretch the country rapidly becomes very rough and rugged and is totally forested.

On the north side of the stream the topography differs slightly from that on the south side, consisting entirely of small hills and rounded swells, with a larger proportion of cleared land, ranging from about two-thirds over the lower part of the basin to three-fourths or more near the Virginia line and around Bristol, while over some of the small drainage basins, such as that of Sinking Creek, more properly known as Beidelmans Creek, from 85 to 90 per cent of the land is cleared and under cultivation or in grass or pasture. The same is true of the area drained by Thomas Creek and of the area known as the Holston Valley, the country being almost level and almost entirely grass covered, the soil being for the most part gray and porous, though some areas of red clay were seen. On the north side of the river, near

Bluff City, zinc is found in paying quantities and mines are now being opened. There are numerous deposits of iron ore throughout the area, and the same is said to be true of all the counties bordering the Unaka Mountains. Over the valleys of Spring Creek (the first tributary entering from Virginia), Wolf Creek, and Fifteenmile Creek the general character of the country is the same as that just described, probably more than 75 per cent of the area being cleared, the soil seeming to be porous and very fertile. Hay and wheat are the chief agricultural products, and as elsewhere in the region a great many cattle are raised. Wherever timber occurs it is hard wood, pine being very scarce. Near Ruthton the proportion of forest land is greater than in any part of this area, and much timber is being cut, forming a profitable industry. Lumbering becomes more and more a source of revenue as the river is ascended.

AREA DRAINED BY THE SOUTH FORK ABOVE JUNCTION WITH THE MIDDLE FORK.

This part of the drainage basin lies almost entirely on the south side of the stream—the area between the forks being too small for the formation of streams of appreciable size—and includes large areas of very mountainous country which is densely wooded. From the junction with the Middle Fork to the mouth of the Laurel Fork the basin is narrow, being shut in by the northward extension of the Holston Mountains, and excepting the land immediately bordering the stream the country is rough and rugged, with steep slopes densely forested, the valleys being extremely narrow and containing little if any cleared land, the land that is cleared being confined, so far as could be ascertained, to the narrow strip bordering the river, and therefore constituting a very small part of the whole.

Above the mouth of the Laurel Fork the mountains recede somewhat from the stream, the strip of arable land becomes wider, and cleared areas are to be found in the basins of some of the tributaries, as on Rosenbaums Creek, where the proportion of cleared land is between two-thirds and three-fourths, while of the whole area lying between the river and the road from Damascus to Holstein Mills about one-third is cleared. The area to the south of the road is entirely in forest, and the slopes are steep and rocky, the country rock being still a limestone formation.

Many sawmills are located near the headwaters of some of the small tributaries, and are engaged in cutting the hard-wood timber. There are also one or two mills along the stream, but they are cutting only a few hundred feet each day.

Widner Creek, Rush Creek, Poge Creek, Mill Creek, Grose Creek, and St. Clair Creek, all tributaries from the south, are small streams draining narrow and confined valleys and rough, mountainous, and forest-covered slopes, the small proportion of cleared land in the basin of each being confined to the narrow strip next to the stream, the

country being rather inaccessible, as roads are few. There is much timber, but owing to the roughness and steepness of the mountain slopes it is exceedingly difficult to lumber it, so that up to the present time very little has been cut.

There is one notable exception to the general character of the country along the river, viz, the area known locally as the St. Clair Bottoms, situated on both sides of the South Fork between Holstein Mills and the Washington County line, extending back 1 or 2 miles on each side of the stream and embracing a large area of very beautiful grazing land, a small part only being cultivated in corn and wheat. These bottoms are broad, and from them the uplands rise very gently, the area being practically all cleared. The country rock is a limestone, a small quantity of which is burned for building purposes and to apply to the land.

Above Holstein Mills the mountains close in again and as a consequence the area is more broken and rough. Very little cleared land is to be seen either along the river or away from it until the head of the stream is reached, when the mountains again recede, leaving the broad and fertile area known as the Rye Valley, which extends from a little below Dickey Creek to and above the junction of Slemp and Cressy creeks, and is rimmed about by high and steep mountain slopes. This valley is very broad and gently rolling, and is almost all cleared and in grass. Dickey, Slemp, and Cressy creeks are small streams draining narrow valleys and areas of steep mountain slopes where the proportion of cleared land is small above the limits of the broad valley just described.

AREA BETWEEN THE SOUTH AND MIDDLE FORKS.

This area is a long and narrow strip, 5 or 6 miles in width at the widest part and about 29 miles long, measured from the headwaters of the two streams to the point of junction, and slopes from the crest of the Blue Ridge toward the southwest, the area being about equally divided between the drainage systems of the two forks.

From the junction of the streams to the slopes of the Pond Mountains the country is level or gently rolling, the hillside slopes being slight. The soil is largely a red clay quite impervious to water, though there are large areas of a light-yellow porous soil. The cleared land forms about three-fourths of the area and the wooded portions are too small and as a rule too widely separated to have much effect on the run-off.

South of Marion the large sandstone areas represented by the Pond and the Brushy mountains are all wooded and quite steep. Even where the timber has been cut away the smaller trees and underbrush have grown rapidly and cover the ground with a dense shade. Some of the slopes, however, are composed largely of a species of talus, small angular fragments of the stone comprising the mass of the uplift, covering them in places to a depth of several feet, where the growth is sparse, consisting of small bushes and straggling trees.

RAINFALL.

The annual rainfall over the basin of the South Fork is comparatively large, averaging probably between 40 and 41 inches per annum, diminishing somewhat as the stream is ascended. Over all the basin the summer rainfall seems greater than that of any other season, heavy rain storms being of frequent occurrence, causing large and rapid rises in all of the streams. Severe droughts are relatively infrequent and are soon broken. The drought of the summer and fall of 1900 was said to be the most severe in the history of the region, and it is thought that the low-water gagings made at that time represent the minimum discharges of the streams.

FORESTS.

The forest growth of the basin is mostly oak, chestnut, and pine, with some spruce, walnut, maple, hickory, beech, birch, dogwood, cherry, ash, locust, and poplar, and still smaller quantities of other woods. There are important lumbering industries, notably those near Bristol, although throughout the area numerous mills, large and small, are working up the raw material. In many places large quantities of tan bark are stripped, much of it going to the great tanneries at Bristol. The chief industry of the region, however, is cattle raising, large numbers of which are shipped annually from this section.

MINERALS.

Iron ore is found at a great many points within the basin, and is being mined at some localities, although from some cause the business seems to be languishing, most of the furnaces being out of blast. Zinc is found near Bluff City, Tenn., and gold, barytes, and fluorspar are found in small quantities at various places. There are large deposits of gypsum in the valley of Walker Creek; sandstone, granite, and dolomite occur in small areas; and limestone of excellent quality is found in abundance everywhere. Near Marion, Va., the limestone is quarried in considerable quantities and is shipped to the alkali works at Saltville, Va., where there are extensive saline deposits.

TRANSPORTATION.

The basin is traversed by the lines of the Southern Railway as far as Bristol. The Norfolk and Western Railroad extends from that point the whole length of the basin, and the Bristol and Elizabethton, the East Tennessee and Western North Carolina, the Holston Valley, and the Ohio River and Charleston Railroad afford comparatively good communication with the greater part of the area.

DISCHARGE MEASUREMENTS.

During the investigation many measurements were made of the river and its tributaries, and one gaging station was established in

the basin, viz, at Bluff City, Tenn. The miscellaneous measurements made on the South Fork and also those made at the gaging station are given in the following table. The measurements made on the tributaries are given in the table on page 53.

Discharge measurements of South Fork of Holston River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-ft.*
July 17	Bluff City, Tenn	E. W. Myers and L. V. Branch.	0.25	378
Aug. 16	do	do	0.25	329
Sept. 25	do	do	1.15	791
Nov. 8	do	do	0.90	681
Dec. 27	do	do	0.60	392
July 23	Below mouth of Middle Fork, Va	L. V. Branch	3.06	228
Oct. 3	do	E. W. Myers	3.21	199
July 28	Below mouth of Laurel Fork, Va	do	2.60	652
Oct. 3	do	do	3.39	149
July 28	Above mouth of Laurel Fork, Va	do	1.51	101
Oct. 3	do	do		48
July 27	Rye Valley, Va	do	6.96	20
Oct. 1	do	do		5

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table which were made at Bluff City, Tenn. In making the other measurements given in the table, however, bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In those cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

WATER POWERS.

A water power of considerable magnitude can be developed at Bluff City, Tenn., where the total available fall is between 15 and 20 feet. The only use of the power at present is by the Bluff City mill, a flouring mill having a capacity of 50 barrels per twenty-four hours, using a fall of from 5½ to 6 feet, which with one 35-inch Victor turbine develops about 30 horsepower. Formerly there was a small cotton mill located here which used about 7 feet of the fall, but that is no longer in operation. A development of power could easily be made at this place, the river being narrow, with high bluffs on each side. The railroad facilities also are good.

Above the pond of the Bluff City mill the stream is comparatively placid until just below the mouth of Dry Creek, where there is a shoal having a fall of about 8 feet in 200 yards. The bed of the river is very rough, being crossed by several ledges of rock and containing many loose bowlders. The banks are rather low, being only about 10 feet above low water.

McClellan's mill, the first mill on the river above Bluff City, is on the north bank of the stream about 50 yards above the mouth of Weaver Creek. It is a small combined sawmill, gristmill, and cabinet shop, using a small amount of power, which is obtained from an undershot wheel and a homemade tub wheel, both using a head of about 4 feet, practically all that is available. It is said that curly maple and curly birch are to be found here in considerable quantities, and that other fine cabinet woods abound.

There is one small shoal in the river between McClellan's mill and the mouth of Beidelmans Creek, but the fall is slight and the locality of no practical importance. At the time this stream was first visited, in the latter part of July, 1900, almost all of the small tributaries in this part of its course were practically dry, the largest carrying less than 0.5 second-foot. The stream itself between the points mentioned consists of a succession of still pools, seemingly quite deep, with a very low current velocity broken by short shoals where the depth of the water ranges from a few inches to about 1 foot, flowing over and among water-worn pebbles from 3 to 6 inches in diameter, with occasional rock ledges crossing, where the principal falls are found.

For some distance upstream from the mouth of Thomas Creek the hills on the north side rise rather steeply from the river's edge to a height of several hundred feet, and the valley on the south side is much narrower than those heretofore described. The country rock along the stream is a much jointed and laminated gray or black slate, striking to the northeast and dipping almost vertically. The river flows over the upturned edges of this slate, making a very rough channel, but one in which the fall is well distributed, there being little noticeable concentration at any locality.

About 200 yards below the mouth of Riddle Creek there is a small mill, known as Rosenbaum's mill, which diverts a few second-feet of water from the river by means of a low and loosely piled rock wing dam, a fall of about 5 feet being obtained through a race 150 yards long.

About 1 mile below the mouth of Fishdam Creek and just above the mouth of a small unnamed branch there is a fall of 5 feet in 300 feet, over a rough and rocky bottom, composed of angular bowlders and rock ledges. There are high and rocky bluffs on the north side of the stream, but on the south side the banks rise to a height of about 10 feet, and then a broad meadow slopes gently away. The facilities for building a good dam and a race at this point are excellent.

Just below the mouth of Fishdam Creek is one of the finest mill sites seen on the river. The current is divided by a small island, at the head of which a low loose-rock wing dam has been built, diverting a small part of the current. Another dam has been constructed about 30 yards above the foot of the island, a total fall of 9 feet being thus obtained, which is used by a small sawmill and gristmill requiring probably about 2 horsepower, which is developed by a small flutter wheel. This mill is said to have a capacity of 600 feet of lumber or 40 bushels of corn a day. Power in large quantity could very easily be obtained here, and although at present the locality is somewhat inaccessible, the graded way for the Holston Valley Railroad passes the mill and the track construction work is only a few miles distant.

Fishdam Creek enters the river at the elbow of a great bend known

locally as the Horseshoe Bend. If the river be followed the distance around this bend is about 2 miles, but the distance across the narrow point of the neck is only about 200 yards. This neck is low, being at its highest point only from 40 to 50 feet above river level. From water to water across the neck there is a fall of between 25 and 30 feet, as determined by the aneroid barometer. It is stated that this neck has been leveled over and the difference in elevation in the water surfaces on the two sides determined to be 26 feet. Should it be desired to develop this power, a tunnel or an open canal could be made across the neck and all or a part of the flow easily be turned through it. On the north prong of the bend the river is rather wide, but a low dam could easily be built, and there are large areas of well-protected bottom land, lying well above high-water mark, which would afford ample room for the necessary buildings. The country rock here is a much laminated and jointed slate, not suitable for building purposes.

The next shoal on the river is just above the mouth of Sharp Creek and the Shady Ford. The river here is full of islands large and small, and the fall is heavy, being about 20 feet in a distance of less than a half mile. The water could easily be carried along the southeast bank and used where desired along the river; or by a short extension the race might be carried around a small hill and Sharp Creek be used as a tailrace. The west bank is high and rocky, with numerous bluffs, and large quantities of stone suitable for rough building operations could be obtained from it. Plenty of timber is to be found in the immediate vicinity.

Some distance above this shoal and about a half mile below the mouth of Jacobs Creek there is a shoal having a fall of 6 feet in 200 feet, with a broad bottom on the west side and a high, rocky bluff on the east side. This power, however, is not considered of importance.

From this point to the junction with the Middle Fork the river could not be closely followed, but several localities with falls of between 6 and 7 feet were noted, the first one about 3 miles below the forks. About a half mile above this fall there is a similar shoal, about 1 mile below the forks there is another, while immediately above the forks there is one having a fall of about 8 feet in 100 yards which could easily be developed, as the banks are very high and steep. The bed of the river is in solid limestone and seemingly is very rough, but the stone in the bluffs quarries well, and a considerable quantity has recently been taken out to construct the piers for the bridge of the new railroad from Abingdon to the Shady Valley, which crosses the river at this point.

About a mile above the junction with the Middle Fork is Glenn's mill, a gristmill using about 24 horsepower, which is developed by a 24-inch turbine working under a head of 7 feet. There is a loose rock wing dam which turns a small part of the water behind an island, at the lower end of which a log dam 7½ feet high has been built, from

which a wooden flume 100 feet long carries the water to the mill. There is never any lack of water at this point, and high water interferes with the operation of the mill not more than four or five days in the year on an average.

Above this point there is no noticeable concentration of fall on the South Fork until the mouth of the Laurel Fork is reached, the fall, though large, being well distributed.

About a mile above the mouth of the Laurel Fork is the Rambos mill, a small gristmill using an 8-foot fall and an unknown amount of power, sufficient, however, to operate three sets of stones. The dam is of timber frames planked over and is about 3 feet high and 150 feet long. It turns a small part of the water into a race about 200 yards long. The mill is old and considerably out of repair.

From this point up to about 3 miles below the village of Friendship there are no mills on the South Fork, though several small mill sites were heard of which in the past had been occupied by small gristmills which have been washed away by the floods to which the stream is subject. About 3 miles below Friendship was the best site heard of on this part of the river and the only one visited. This is known as the Buchanan site, and it is stated that there was formerly a very good gristmill here, but nearly all vestiges of it have disappeared. The fall used was about 12 feet, though a much greater fall could be made available by the construction of a suitable dam, which could be made from 40 to 50 feet high without flooding any valuable land.

A short distance above Friendship is Vail's mill, a combined sawmill, gristmill, and planing mill, using 78 horsepower, which is developed by three Success turbines of 24, 27, and 30 inches diameter, respectively, all working under a head of 12 feet. The miller at this mill stated that he had measured the river at its lowest stage and found a flow of 8,000 cubic feet per minute. The dam is of timber frames planked on the upstream side, 12 feet high and 144 feet long, forming a pond 500 yards long. The sawmill has a capacity of 6,000 feet B. M. per day, and the gristmill a capacity of 30 barrels. The year round there is plenty of water to run all of the machinery in this mill at the same time. It is estimated that with a head of 12 feet the river at this point has a flow sufficient to develop 145 net horsepower, and that from this point to the mouth of the Laurel Fork 100 horsepower could be developed every half mile.

About 4 miles above the Vail mill is Love's mill, located just below the Smyth County line. This also is a combined sawmill, gristmill, and planing mill, and is said to use 36 horsepower, developed by a 21-inch Success turbine rated at 20 horsepower when working under a head of 9 feet, and three wooden tub wheels developing a total of about 16 horsepower. The dam is of timber frames planked on the upstream face, and is in fair condition. It is 9 feet high and 150 feet long. It backs the water a distance of three-fourths of a mile, there being little slope in the river above the dam but a considerable fall

just below it. There is no race, a wooden flume 60 feet long carrying the water from the dam to the wheels.

The next mill on the river is the St. Clair roller mill, located about 2 miles below the Holstein mill, at Holstein Mills, in the area known as the St. Clair Bottoms. There is a fall of about 10 feet at this place, and the power used is developed by one 20-inch Success turbine, rated at 20 horsepower; one 35-inch Leffel wheel, Standard pattern, rated at 25 horsepower; and one 20-inch Burnham Brothers' wheel, rated at 20 horsepower; making a total of 65 horsepower when all of the machinery at the mill is in operation. The dam is a timber crib structure planked over on the upstream face, 7 feet high and 100 feet long, backing the water about 500 yards. The race is 200 yards long and gives a fall at the wheels of 10 feet. The mill is rated at 45 barrels per day and has a capacity of between 200 and 300 feet of lumber. At the lowest stages of flow there is not enough water in the river in this part of its course to operate all of the machinery in the mill at the same time.

The next mill on the stream is the Holstein mill, a combined sawmill and gristmill, evidently very old and greatly out of repair, using a fall of 12 feet and an unknown amount of power. This site is a very fine one for a small plant. The dam is of timber frames planked on the upstream face, and is very leaky. It is 12 feet high and nearly 200 feet long. There is no race, a short wooden flume leading the water directly to the wheels, two homemade affairs built on the turbine principle and yielding an unknown amount of power.

About 100 yards below this site is the site of an old woolen mill abandoned about ten years ago. Here there was a 9-foot dam about 150 feet long. At first two small turbines were used, but these required so much water that a race was dug from the dam of the upper mill, and a breast wheel 14 feet in diameter and 9 feet face was installed. This site is said to be one of the best on this part of the stream, suitable for any kind of a mill but particularly adapted for a woolen mill. The mill property includes dwelling houses, school, and church, all in good repair. The mill building has been torn down, however, and any power development would have to be made from the beginning. The valley above this mill is more hilly and is narrower than that below, which, particularly in the part known as the St. Clair Bottoms, is very broad, being 4 miles or more wide and extending back in a gentle rise to the foot of the mountains, with practically all of the land cleared.

Above this there are no mills on the stream until the Rye Valley is reached. In the upper part of that valley there is a small gristmill operating one pair of stones by a large overshot wheel and using a very small amount of power. It is only 5 miles from this mill to the head of the stream, and above it the river is too small to furnish power in appreciable quantities, although throughout the upper part of the stream, from the St. Clair Bottoms to the head of the river, the

fall is very great, the stream being almost one continuous rapid. As determined by the aneroid barometer the fall between the end of the big bend immediately below the Rye Valley and the first ford below—a distance of about 1 mile—is 20 feet; between that point and the mouth of Pomer Creek it is 30 feet; between Pomer Creek and the river surface 2 miles above Holstein Mills it is 140 feet; and between the latter place and the ford below the old woolen mill—a distance of about 2½ miles—it is 150 feet. Through the St. Clair Bottoms the fall is much less, but it is still large, and there are many places where falls of from 10 to 15 feet could be utilized by the construction of dams of suitable height.

TRIBUTARIES OF SOUTH FORK OF HOLSTON RIVER BELOW JUNCTION WITH THE MIDDLE FORK.

DISCHARGE MEASUREMENTS.

During the investigation the drainage basins of all the important tributaries of the South Fork were visited and measurements were made of most of them. The results of the measurements on the tributaries below the junction with the Middle Fork are given in the following table, in order upstream:

Discharge measurements of tributaries of South Fork of Holston River below junction with the Middle Fork.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Sept. 25	Hatcher Creek	One-half mile above mouth, Tennessee.	E. W. Myers	5.92	0.34
July 20	Sinking Creek	One-half mile above Paperville, Tenn.	L. V. Branch	3.60	3.48
July 29	do	At mouth, Tennessee	E. W. Myers	4.92	11.00
Sept. 25	do	do	do	4.42	9.09
Do.	Thomas Creek	Below railroad bridge, Tennessee	do		2.46
July 20	Riddle Creek	At mouth, Tennessee	do	12.19	2.00
Sept. 25	do	do	do	11.13	3.00
July 20	Jonah Creek	do	L. V. Branch	11.06	4.00
Sept. 25	do	do	E. W. Myers	11.42	4.00
July 20	Fishdam Creek	do	do	5.25	5.85
Sept. 26	do	do	L. V. Branch	5.26	2.47
July 21	Sharp Creek	do	E. W. Myers	5.36	1.16
Sept. 26	do	do	do	5.33	1.19
July 21	Jacobs Creek	do	L. V. Branch	9.10	2.07
Sept. 27	do	do	E. W. Myers		2.00
July 21	Spring Creek	1 mile above mouth, Virginia	L. V. Branch	0.90	13.00
Sept. 27	do	do	E. W. Myers		10.00
July 21	Wolf Creek	Lower ford of main road up the river, Virginia.	do	2.35	7.00
July 23	do	do	L. V. Branch	2.36	7.00
Sept. 27	do	do	E. W. Myers	2.21	12.24
July 21	Denton Valley Creek.	At mouth, Virginia	L. V. Branch	5.73	6.00
Sept. 27	do	do	E. W. Myers	5.73	4.04
July 23	Fifteenmile Creek.	do	L. V. Branch	4.45	7.37
Sept. 27	do	do	E. W. Myers	4.23	10.46

NOTE.—In making the measurements recorded in the above table, bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

On the following pages are given brief descriptions of the drainage basins and water powers of the principal tributary streams in this portion of the basin of the South Fork, in order upstream.

INDIAN CREEK.

The first tributary investigated was Indian Creek, which enters from the south, near Bluff City, Tenn., and has a total length of about 7 miles, following its windings. The country rock observed over the basin was a slate, brownish-black or gray in color, much laminated and broken, striking N. 70° E., and dipping sharply to the south, from 80 to 85 degrees in some cases. As the mouth of the stream was approached ledges of limestone made their appearance on the tops of the hills.

For the first 2 or 3 miles above the mouth the topography consists of low, rounded hills and broad, flattened swells, cleared to the top for the most part, and under cultivation in grain or grass, the area being about equally divided between those products. The woodland in this part of the basin amounts to only about 10 per cent of the area, but as the stream is ascended the hills are higher and more rugged, with steeper side slopes, and the proportion of cleared land is much smaller, being not more than one-third in the upper part of the basin. Over the lower part of the area the woods are composed almost entirely of hard-wood trees, but near the headwaters these give place to pine.

The fall of the stream is large, being between 450 and 500 feet, averaging between 65 and 70 feet to the mile. Very little of it is utilized, however, but there are three small mills, each using from 10 to 12 feet and operating one pair of stones by means of overshot wheels. Although these three mills use a very small amount of power, at the time the stream was first visited, in July, 1900, it was carrying too little water to operate them. The flow at the mouth was estimated to be about 1 cubic foot per second, though it could not be measured, owing to the shape of the channel. The hillside slopes vary from 15 degrees near the mouth to 50 or 60 degrees near the head of the stream.

In the first 2 or 3 miles above the mouth of the creek traces of three well-defined stream terraces were observed, the upper one being the uplands, the second one a narrow strip of level land lying from 20 to 25 feet above the present level of the stream, following its course but from 100 to 150 yards distant and sloping down very sharply to the level of the present bottom lands, which constitute the third member of the series. The descent in many cases is almost vertical.

Between the mouth of Indian Creek and the Dry Branch, the next tributary upstream, is an old mill known as Worley's mill, not now in operation, which was run by water from a big spring or sunken creek. At the time this stream or spring was visited it was carrying a quantity of water too small to operate the mill, but the discharge was estimated to be approximately 2 second-feet.

DRY CREEK.

Dry Creek, or more properly the Dry Branch, is the next tributary above Indian Creek, and like that stream it enters the river from the south. It has a total length of about 4 miles. The drainage area, which consists almost entirely of gentle swells and small grass-covered slopes or hills, is largely cleared land. At the time the stream was visited it was estimated to be carrying about 0.25 second-foot, the amount being too small to measure.

WEAVER CREEK.

Weaver Creek, the next tributary entering from the south, has a total length of between 5 and 6 miles. The part of the drainage basin lying near the river is very similar to the basins of Indian Creek and the Dry Branch just described, but as the stream is ascended the country becomes rapidly more steep and broken, on account of the rising spurs of the Holston Mountains. It is estimated that two-thirds of the total area drained by this creek is cleared land, the the greater part of it being grass covered. The discharge was estimated to be about 0.5 cubic foot per second, the quantity being too small to admit of measurement with a current meter.

HATCHER CREEK.

The next tributary is Hatcher Creek, locally known as Tow String Creek. At the time of the first visit, in July, this stream was dry, carrying no water for a mile or more above its mouth; but at the time of the second visit, September 25, although the stream discharged no water into the river it was carrying 0.34 second-foot about a half mile above its mouth. This flow, however, sank gradually into the earth within a distance of about 100 yards. The discharge was gaged just above this sink. It seems probable that this stream would begin to discharge water into the river when carrying a small quantity more than at the time of measurement. Its flood discharge is about 4 feet, and like the other streams in the region it rises and falls rapidly.

A great part of its drainage basin is in forest, and the character of the topography is much bolder than that of the areas lying farther to the west, the hills rising higher and the slopes being much steeper.

MORRILLS CREEK.

The next stream entering the river is Morrills Creek, which is about 6 miles long and drains a larger area than any of the foregoing tributaries. Near its mouth the character of the topography is similar to that of the other basins described, but as the stream is ascended the country becomes very rough and broken and the hillside slopes very rough, rocky, and steep. There is much cleared land near the river,

but so far as could be ascertained there is none near the headwaters. Despite its large drainage basin, the amount of water carried by this creek at its mouth at the time it was visited was too small to admit of measurement with a current meter, but it was estimated to be about 1 cubic foot per second.

SINKING CREEK.

The next tributary—the first of importance entering from the north—is Sinking Creek, more properly known as Beidelmans Creek, for Sinking Creek is properly a small tributary of the latter stream. It has a total length of about 12 miles. The upper part of its basin, from Paperville to the head, is broad and flat, consisting of low ridges and flattened swells cultivated to the top, from 85 to 90 per cent of the area being cleared land. From Paperville toward the mouth, however, for about 2 miles the hills close in on the stream, there is considerable fall in the channel, and practically none of the land is cleared, the hillside slopes being too steep and rocky to admit of cultivation. Below this short strip the character of the country is similar to that of the upper part of the basin. The timber, which occurs largely in the 2-mile stretch just noted, is almost all hard wood, and lumbering is an important industry. So far as known there are no mines or minerals in the basin, though large deposits of iron ore are found not far distant.

There are a number of mills on Sinking Creek, all within the 2-mile stretch described, where the stream has cut its way through the Great Knobs, leaving a very rough and steep channel. The first one is about a half mile above the mouth of the creek and is known as Beidelman's mill. It is a small gristmill operating two sets of stones and using a fall of about 8 feet, the power being developed by a 14-inch turbine yielding about 10 horsepower. The dam is of wood, about 2½ feet high and 100 feet long; the race is about 100 yards long, in earth and wooden flume.

Some distance above this and a short distance below the village of Paperville is Nutty's woolen mill, which uses about 14 horsepower, developed by a 14-inch Little Giant double turbine working under a head of 13 feet, which could be increased to 16 feet. This mill operates one set of woolen machinery.

About 200 yards above Nutty's mill is Bruce's mill, which uses a fall of 35 feet on a 12-inch James Davis turbine yielding 12 horsepower and operating one set each of corn and wheat stones as well as sawmill and planing machinery. There is no dam at this mill, the water being turned directly into the race. There is plenty of water except when the mills above close down.

About 200 yards above Bruce's mill is the planing mill operated by J. T. Nutty, where about 14 horsepower is developed by a 13½-inch Burnham turbine working under a 17-foot head, which is used to

operate a full line of sash, door, and blind machinery. The dam is 3½ feet high and 36 feet long, making a pond 200 feet in length. There is at all times plenty of water in the stream to develop this power, and it is stated that the fall could easily be increased to 24 feet.

A short distance above the Nutty planing mill is the sawmill operated by J. H. Maddox, where the fall is 18 feet, about 10 horsepower being developed by a homemade wheel built like a turbine. The plant consists of a small sawmill, including planer, turning lathe, and a pair of corn stones. The dam is 60 feet long and 3½ feet high, backing water to the tailrace of the mill above, a distance of about 100 yards. The race is of wood and is 96 feet long.

One hundred yards above the Maddox mill is the flouring mill of the Farmers' Milling Company, located in the village of Paperville. This is a 40-barrel roller flour mill operated by an 18-foot overshot wheel of 4½ feet face, which is said to furnish 20 horsepower. The flow of the stream at the time of the visit in July was said to be sufficient to operate the mill only about half the time, but for nine months of the year the stream furnishes water sufficient to run the mill night and day. A gaging was made of the water in this flume.

The next mill is about one-fourth of a mile above Paperville and about 2½ miles below Bristol. It is known as the Rutherford mill, and is a gristmill operating one pair of wheat stones. The dam is of wood, 8 feet high, and gives a fall of 11 feet at the mill, through a wooden race about 100 feet long. The power is developed by a 20-inch New American turbine yielding 15 horsepower. It is stated that there is generally sufficient water in the stream to operate this mill all of the time, but when visited in July the flow of the creek was insufficient to operate it more than a very small part of the time. The miller, who had known the stream many years, stated that it was at a lower stage than at any time within his recollection.

The total fall of the creek between Rutherford's mill and Nutty's woolen mill is said to be approximately 135 feet; by aneroid measurement it was determined to be 130 feet. The fall used by the several mills aggregates 121 feet, all within a distance of less than a mile.

THOMAS CREEK.

The next tributary, entering also from the north, is Thomas Creek. Its drainage basin is level to gently rolling, and is from 85 to 90 per cent cleared land, a very large proportion of which is grass covered. At the time of the July visit it was thought that the stream was carrying too little water to be measured with a current meter, but at the time of the September visit the creek was somewhat higher and was gaged a few hundred yards above its mouth. It was carrying 2.46 second-feet. The flood rise is about 5 feet. There is one small combined sawmill and gristmill on the stream, using a small amount of power, developed by an overshot wheel. Formerly there was a mill near the mouth of the creek, but it has been torn down.

RIDDLE AND JONAH CREEKS.

The next two tributaries entering from the south are known as Riddle Creek and Jonah Creek, respectively. These are two small streams of about the same size and having drainage basins of the same general character. Much of the timber has been cut from the area drained by them, and the proportion of cleared and cultivated land is about one-third of the whole. The forest growth, or more properly the undergrowth, on the remainder of the area is very sparse, owing to extensive lumbering operations. It is said that since the lumbering began the streams are much more flashy, falling much lower and rising higher and more rapidly, and that the floods are much more destructive than formerly. These streams attained their minimum stage of flow during the summer and fall of 1900. The average rise at the mouth of each is from 4 to 5 feet. Corn is the principal product of the basin, and no mines or minerals of any kind are known.

FISHDAM CREEK.

The next tributary, which enters the river from the east, at the head of the Horseshoe Bend, is Fishdam Creek. It drains an area entirely forest covered, excepting a few acres at its mouth. The immediate valley is very narrow and swampy and is covered with dense laurel thickets. The hills are steep and at the lower end of the valley are very high and mountainous. The country rock of the basin is slaty in character. The stream seems to have a large low-water flow, and is said to be less flashy than Jonah Creek or Riddle Creek, whose basins have been deforested, but active preparations are now being made to cut the timber in this area also. The Holston Valley Railroad is being graded along its course as rapidly as possible, and after that is completed the timber will rapidly disappear. Fishdam Creek, like all other streams in this section of country, reached its lowest stage during the summer and fall of 1900. During floods the rise at its mouth is about 4 feet above its average water level.

SHARP CREEK.

Sharp Creek also enters the river from the east. It is a small stream draining an inconsiderable area, the largest part of which is in forest, although there is considerable cleared land near the mouth of the stream, where the hillside slopes are gentle, ranging from 10 to 15 degrees. As the stream is ascended the hills are steeper and there is no cleared land. The cleared land in the basin amounts to about one-third of the area. On it fine vegetables and fruits can be grown, grapes thriving especially well. Much of the pine and poplar has been taken out of the forests, but the oak, beech, and chestnut remain. Considerable tan bark has been stripped, but very little has been taken out.

The slopes of the mountain sides are steep, being in some cases 60 degrees or more, and they are often covered with angular fragments of broken stone ranging in size from bits a few inches in diameter to blocks several feet across. The soil of the mountain slopes seems composed entirely of vegetable mold, which is mingled with these fragments. Near the tops of the mountains there is very little rock, the surface being covered with vegetable matter, black and moist, and the forest growth being very dense and luxuriant, composed for the most part of oak, with small quantities of chestnut, hemlock, and spruce. The stream is subject to fluctuations of about 6 feet.

The first mill on the creek is Lawson's mill, a small gristmill operating a single pair of stones by means of a small flutter wheel which yields an unknown amount of power. There is a fall of 14 feet available at this mill, but the quantity of water is very small. Moore & Graham's mill is a small sawmill near the headwaters of the creek. It uses about 14 horsepower and cuts about 500 feet of lumber a day.

Sharp Creek has a large fall and there are many sites where mills could be located.

SPRING CREEK.

The next important tributary is Spring Creek, which enters from the north, a short distance above the boundary line between Virginia and Tennessee. Its drainage basin possesses the same general characteristics as the other basins, consisting of broad, low, and rounded hills and ridges, with wide, flat spaces between, all the slopes being very gentle, and there being from 75 to 90 per cent of cleared land, the larger part of it in grass, hay, and grain, which are the chief agricultural products. In this basin limestone is the country rock and slate is seldom seen. The creek has periods of very low flow, and during floods it rises rapidly to a height of about 5 feet above its low-water level.

The first mill on the stream—Combes & Garrett's—is about a mile above the mouth. It is a gristmill containing two sets of buhrs, two stands of rolls, and a corn mill, the machinery requiring about 10 horsepower for its operation. The power is developed by a 16-foot overshot wheel with 42 inches face, which is said to yield 16 horsepower. The dam is 250 yards above the mill and is of stone, 7 feet high and about 100 feet long. By the use of a turbine 21 feet fall could be obtained at this place.

King's mill, the second mill on the stream, is 2 miles above its mouth. It is a gristmill operating three sets of buhrs driven by a 40-inch Leffel turbine working under a head of 10 feet and yielding an unknown amount of power. It is stated that 8 horsepower is sufficient for the operation of the machinery. The dam, which is at the mill, is of timber frames planked over on the upstream face, and is 10 feet high and 30 feet long, giving a pond 300 yards in length.

Hawkins's mill, the next mill above the King mill, is a sawmill having a capacity of about 2,000 feet a day, using an unascertained amount of power, which is developed by a 36-inch turbine working under a head of 12 feet. There is no race, the dam, which is of stone, 12 feet high and 35 feet long, being located at the mill. It is said that ordinarily there is sufficient water in the stream to operate this mill all of the time, but when it was visited in July the entire flow of the stream was leaking through the dam.

On the top of a hill by the roadside just before Hawkins's mill was reached three or four potholes were noticed which had been worn out in the solid limestone, the country rock over this part of the area. These holes were unmistakably due to the action of water flowing in a stream channel for a considerable period, and as they are more than 100 feet above the present level of the creek they would seem to indicate material changes in this country during very recent geologic times.

JACOBS CREEK.

The next tributary is Jacobs Creek, which flows in from the east and drains a large area of rolling country, slightly broken near the river but very rough and mountainous near the headwaters. The basin is largely wooded, in a very heavy forest growth, and probably less than 10 per cent of the land is cleared. During low water the stream falls to a very low stage, and during floods it rises about 5 feet at the mouth. So far as could be learned neither mineral nor lumber industries are carried on in this basin, nor are its waters used to operate any mills.

WOLF CREEK.

Wolf Creek, entering from the north, is the next tributary. It is about 10 miles long and drains a large area. The valley is wide and flat and is almost entirely cleared and grass covered. Limestone is the country rock, slate being seldom seen, though an occasional ledge of much jointed and laminated slate was noticed. The fall of this stream seems to differ greatly from that of other streams of the region, in that it consists of a succession of vertical plunges of from 1 to 6 feet, the intervening stretches being comparatively still and placid water. Along the upper part of the stream, near Vance's mill, the fall is very great, amounting to more than 50 feet in 1 mile, while above and below that point, where the creek flows through and between the Great Knobs, the fall is much less.

The largest fall on the creek is a few yards above its mouth, and is said to have been measured with an engineer's level and to be about 100 feet in 100 yards; the aneroid barometer, however, gave it somewhat less than that. This fall is the site of the first mill on the stream, known as the Falls mill, owned by Pitt & Nutty, of Stump, Va.

Formerly there was a fine mill here, but of late years it has been suffered to fall into disrepair. At the time it was visited in July, however, repairs were in progress, and it was stated that a roller flour mill of 40 barrels' capacity was to be installed at once. The log dam at the head of the falls is 8 feet high and 50 feet long. The race is about 100 feet long and gives a fall at the mill of 36 feet. The power is to be developed by a 12-inch double turbine, which will yield 35 horsepower under the head stated. It is claimed that this site will develop 280 horsepower the year round by using all of the fall, but there is some trouble from lack of water, which at times is held back by the mills upstream until late in the day.

Vance's mill, the next one on the creek, is about 2 miles south of Abingdon, at the upper end of the gorge referred to. It is a small sawmill and gristmill of two runs of stones, the sawmill and each pair of stones being operated by a separate overshot wheel about 16 feet in diameter. No estimate of the amount of power necessary for the operation of the machinery could be obtained. The dam is a timber structure 12 feet high and 100 feet long, and is very leaky. The race is a wooden flume about 150 feet long, giving a fall of 18 feet at the wheels. This power could be greatly increased by taking in a fall of about 6 feet just below the mill and using all of the water in two small turbines.

DENTON VALLEY CREEK.

The next tributary is Denton Valley Creek, one of the largest streams flowing into the South Fork. For the first 3 miles above its mouth there is a large proportion of cleared land in the basin, amounting to probably one-third, practically all of it grazing land. In even the cleared areas the hillside slopes are steep, ranging from 15 to 30 degrees, and show a great deal of exposed rock, everywhere a limestone. Farther upstream, however, the country becomes very rough, rugged, and mountainous, and is densely forested, with a soil that is seemingly very moist all of the time. As the creek is ascended the limestone of the lower part of the basin gives place to a slate, and near the top of the mountains the slate is replaced by a sandstone which on disintegrating becomes a fine, light-yellow to white sand. This stream falls very low and has a maximum rise of 4½ to 5 feet, rising and falling rapidly, although less rapidly than others in the immediate vicinity.

There is but one small mill on the creek, and there is no information concerning it at hand. Near the mouth of the stream are the remains of an old bloomery furnace, seemingly out of operation for many years. As no ore was heard of in the immediate basin it must have been brought from the deposits in the Shady Valley, which can be reached from the head of the stream.

FIFTEENMILE CREEK.

Fifteenmile Creek, entering the river from the north, is the largest tributary. Its drainage basin seems entirely similar, especially as to soil, country rock, and topography, to the area drained by Wolf Creek. The fall occurs in the same succession of plunges and pools as noted on the latter stream, and like it there is at the mouth a very heavy fall in a short distance, in this case amounting to between 135 and 140 feet in about 1 mile. In this part of its course the creek has cut away a deep gorge, and all of the fall could be utilized with a comparatively small expenditure of money. The flow of the stream is ample to furnish a large amount of power from the fall. A short distance back from the stream the country is flat and has the same general characteristics as noted for the limestone areas.

There is but one mill on this stream. It is at the head of the fall mentioned and is known as the Parks mill, being a combined sawmill and gristmill. The latter operates two sets of stones, one for corn and one for wheat, the power for both being furnished by one wheel, a 16-foot overshot wheel of 5-foot face. The old jig sawmill is operated by a small flutter wheel. The dam is a timber-crib structure planked on the upstream side, and is 8 feet high and 50 feet long. The race is short, partly in excavation and partly a wooden flume. It is stated that the stream never falls so low as to make it necessary to use all of the water in the operation of the mill, and according to the best information obtainable it reached its minimum stage of flow during the season of 1900.

TRIBUTARIES OF SOUTH FORK OF HOLSTON RIVER ABOVE JUNCTION WITH THE MIDDLE FORK.

DISCHARGE MEASUREMENTS.

All of the important tributaries of the South Fork below the junction were visited during the investigation, and measurements were made of most of them, the results of which are given in the following table, in order upstream:

Discharge measurements of tributaries of South Fork of Holston River above junction with the Middle Fork.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
July 28	Beaverdam Creek.	Damascus, Va	E. W. Myers	11.36	189.00
Oct. 3	do	do	do	12.26	32.40
July 29	Whitetop Creek	At mouth, Virginia	do	5.47	100.00
Oct. 2	do	do	do	5.72	34.30
July 29	Atcheson Creek	Near Head of Laurel, Tenn	do	1.82	4.32
Do	Laurel Fork of Holston River.	One-half mile above Laurel Bloomery, Tenn.	do	2.06	23.00
Do	do	Near Laurel Bloomery, Tenn	do	5.12	61.00
July 28	do	One-half mile below Damascus, Va.	L. V. Branch	3.56	351.00
Oct. 3	do	do	E. W. Myers	4.61	88.14

Discharge measurements of tributaries of South Fork of Holston River above junction with the Middle Fork—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
July 28	Rush Creek	Ford 100 yards above mouth, Virginia.	L. V. Branch	3.63	4.20
Oct. 2	do	do	E. W. Myers		2.00
July 27	Mill Creek	One mile above mouth, Virginia.	L. V. Branch	4.32	18.00
Oct. 2	do	do	E. W. Myers	4.43	13.03
July 27	Grose Creek	At mouth, Virginia	L. V. Branch	3.88	2.00
Oct. 2	do	do		([a])	
July 27	St. Clair Creek	do	E. W. Myers	5.76	8.27
Oct. 2	do	do	do	5.94	2.00
July 27	Hogtrough Creek.	Lower ford of main road, Virginia.	do	0.87	9.00
Oct. 2	do	do	do		1.00
July 27	Pomer Creek	At mouth, Virginia	do	2.10	39.00
Oct. 1	do	do	do	2.29	5.00
July 27	Jim Scot Branch	do	do		4.12
Oct. 1	do	do	do		0.50

[a] Almost dry.

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream—the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

On the following pages are given descriptions of the drainage basins and water powers of the principal tributaries of the South Fork above the junction with the Middle Fork, in order upstream.

LAUREL FORK.

The first important tributary of the South Fork above the junction with the Middle Fork is the Laurel Fork, or Laurel Creek, as it is often called, which rises in the northwestern part of Johnson County, Tenn., and flowing in a general northerly and northwesterly direction empties into the South Fork about 4 miles above the junction with the Middle Fork, being joined in its course by two streams as large as itself, viz, Beaverdam and Whitetop creeks. It drains a rough, steep, and mountainous area containing a very small proportion of cleared land, which is confined to the small tracts lying along the stream below Damascus and to the broad meadows about the towns of Head of Laurel and Laurel Bloomery, but these are very inconsiderable in comparison with the total area drained.

Between the mouth of the creek and the first ford there is a fall of about 10 feet, and about 100 yards above this ford there is another fall of from 6 to 7 feet over rock ledges which cross the stream at right angles. Above this the average fall per mile is very large, and though it is well distributed there are a number of places where fine mill powers could be obtained by building dams; and as the banks are high and steep and the slope of the channel is great, no arable land would be flooded. As a rule the banks on the north are precipitous cliffs of limestone from 100 to 150 feet in height, while

on the south side the banks are lower and in places wide bottoms spread out.

There is a fall of about 50 feet between Damascus and the mouth of Whitetop Creek, a distance of about 2 miles. The valley along this stretch is quite narrow and the banks are high, there being only two or three strips of clearing, which lie well above the limits of high water and are of small area, from three-fourths of an acre to 1 acre each. The hills rise steeply from the river, and the opportunities for building high dams are numerous.

Above the mouth of Whitetop Creek the fall of the stream is very great, being between 265 and 270 feet between that point and the first ford below the town of Laurel Bloomery, a distance of about 4½ miles, making the average fall about 60 feet to the mile. Along this portion of its course the stream falls continuously over ledges and bowlders, and there is no stretch of still or smooth water. In places the fall is greatly concentrated. The valley is very narrow, and the hills rise almost perpendicularly from the stream to heights of from 200 to 300 feet. There is much white pine and spruce throughout this section, and there seems to be absolutely no cleared land upstream from the mouth of Whitetop Creek until near Laurel Bloomery. There is only one small tributary stream in this distance, but there are many springs, and the stream gains a large amount of water from them and from seepage between the rock layers. Near Laurel Bloomery the valley widens out and contains much cleared land, practically all of it in grass. The site of the only furnace is about a half mile from the lower end of the valley. No trace of it remains, however, except remnants of the log dam and some heaps of cinders.

Between Laurel Bloomery and the gap or divide separating the waters of the Laurel Fork from those draining into the Watauga, the general appearance of the valley is very like that of the lower part of the Holston Valley, consisting, as it does, of broad, low, and gently rolling swells, almost entirely cleared and grass covered, with herds of cattle feeding over them and with the general appearance of prosperity which marked the other area. The upward slope is gradual, and the whole character of the stream seems in every way different from that of the lower part of its course.

Although power in large amounts could be obtained almost anywhere on the Laurel Fork, very little use has been made of its waters. The first power used is at the mill of A. A. M. Mock, about 1½ miles above the mouth of the stream. This is a combined sawmill, gristmill, roller mill, and flour mill. The buildings are old and greatly in need of repairs. The available fall is 10 feet, and the water is turned onto a 20-horsepower Leffel turbine, used in the operation of the flouring mill and the gristmill, while an old, homemade wheel operates the sawmill. The flour mill has a capacity of 30 barrels per day, the sawmill a capacity of less than 1,000 feet. The dam, which

is of logs, is about 200 yards above the mill and is 4 feet high and 150 feet across the top.

The first power development in the valley, near Laurel Bloomery, is the pipe factory, which uses a small amount developed by a 10-foot overshot wheel with 4 feet face. This factory manufactures pipe stocks from laurel burls. About 200 yards above this is a small gristmill with only one run of stones, using a fall of 10 feet. Above this gristmill there is no utilized power until the mouth of Gentry Creek is reached, where Robinson's mill, a small gristmill of one run of stones, is located, taking water from Gentry Creek and using a fall of about 10 feet and a very small amount of power. A short distance above this mill on Gentry Creek there is a similar mill on the Laurel Fork. As far as the mouth of Atcheson Creek the fall is small and there are no mills, the creek flowing placidly along between wide and fertile bottoms.

Limestone becomes less abundant as the creek is ascended, and much gneiss, quartz rock, and sandstone make their appearance, while occasionally a thin stratum of a species of conglomerate composed of rounded and water-worn pebbles firmly cemented together and lying conformably with the limestone is to be seen.

The Laurel Fork receives two large tributaries and a number of small ones. The first tributary of importance as the stream is ascended is Beaverdam Creek, which enters just below the village of Damascus.

Beaverdam Creek.—This stream rises in the curious elevated valley between the Holston and the Iron mountains which is known and famed throughout the country as the Shady Valley. Throughout the greater part of its length the stream is inaccessible, there being no roads traversing the area, which is very rough, rugged, and mountainous, and is entirely forest covered, except for the small area of cleared land in the Shady Valley. A railroad, however, is now being built along the creek to tap the forests of the Shady Valley, and the country will soon be opened for settlement and for lumbering.

There is only one mill on the stream, and this is located a few yards above its mouth, in the village of Damascus, and is known as Wright's mill. It is a small wood-working shop and corn and chop mill, requiring about 16½ horsepower, which is developed by a 16-inch Little Giant turbine working under a head of 16 feet and using only a very small part of the water carried by the stream. The race is a wooden pipe 1,000 feet long, which follows the level of the stream. The dam is 1 foot high, barely sufficient to turn aside a small part of the water, and of course it gives no pond. At the time the stream was visited in October it was discharging 32.4 second-feet, and was said to be 6 or 8 inches above its extreme low-water mark. The flood rise at this point is about 4 feet.

Indications seem to point to the fact that the Shady Valley was at one time an old lake bed, or at any rate that still water had much

to do with its present formation, since in many places timber is found buried several feet below the surface of the ground. The valley floor is rather level, though seemingly higher in the middle than at the edges. The soil is deep, rich, and moist, being very swampy in places, owing to insufficient drainage. The forest growth is very luxuriant, chiefly white pine and spruce, though some chestnut and other trees are found, some of them of great size, being 100 feet to the first limb. It is stated that the timber in the valley will average 10,000 to 12,000 feet B. M. per acre, and that some tracts will run as high as 50,000 feet per acre. In the swampy areas the soil seems to be entirely a rich, black, vegetable mold, in many places very acid and requiring the application of lime before it can be cultivated with success. In the higher parts of the valley the soil is of a light-yellowish color, with some clay, and fine crops of corn and wheat are produced. The lower part of the valley is more broken and hilly than the upper part, and the proportion of cleared land is much less, diminishing to nothing between 2 and 3 miles below the town of Shady. The Empire Lumber Company is now constructing a large sawmill in this valley. All bricks necessary for their building operations have been burned from a fair quality of brick clay found on the spot.

Whitetop Creek.—This is the next tributary of the Laurel Fork, entering that stream about 2 miles above the mouth of Beaverdam Creek. It drains a very large area, which is entirely forested, the basin being covered with high and rugged mountains having steep and rocky slopes. The fall in the creek is said to be very great and to be much concentrated in places, making wild and picturesque scenery. There are no roads traversing the basin, with the exception of one leading to Whitetop Mountain, so that the country is inaccessible unless the creek be waded. At the time of the July visit the stream was carrying 100 second-feet of water and was said to be 5 or 6 inches above its low-water level. Its extreme flood rise is between 6 and 7 feet. The timber found in the basin includes all of the varieties usually found in the high mountains, and the country rock is reported to be a limestone over the lower part of the area, giving place to metamorphic rocks as the stream is ascended. Some of the higher mountains on the borders of this basin are said to be among the most picturesque in all the mountain region, Whitetop and the views obtainable from it being particularly beautiful. This mountain is a summer resort, being a favorite place for mountain parties. The construction of the railroad up the valleys of the Laurel Fork and Beaverdam Creek will in a measure open the valley of Whitetop Creek also, and will render practicable the development of many of the water powers along its line. This will probably be the result, the power being used in the operation of small flouring mills, which will thus be enabled to find a market for their products, or in woodworking establishments, for which this section offers a very fine field,

as material of the best quality exists in abundance on almost every mountain side. A beginning in this direction has been made by the establishment at Abingdon and at Laurel Bloomery of small mills for working the laurel burls into pipe shapes, from which so-called French briar pipes are manufactured. So far as could be ascertained there are no mining operations in this basin and no minerals occur in profitable quantities.

ROSENBAUMS CREEK.

Rosenbaums Creek, or, more properly, Rosenbaums Branch, is the next tributary of the South Fork. This is a small stream not more than 4 or 5 miles' long, draining a narrow valley and discharging a quantity of water too small to be measured with a current meter, but which was estimated to be about 0.5 second-foot at the time of the visit in September. This is, however, not the discharge from the whole area, for as the stream was ascended the channel was found to be perfectly dry less than a mile above the mouth, though the stream was carrying an appreciable quantity of water about 1½ miles above the mouth, the entire flow sinking into the earth. So far as seen the basin consists of rather low hills, grass covered, with very steep slopes, 40 degrees in some cases. The proportion of cleared land is large, being between two-thirds and three-fourths of the area, and is confined to a strip lying along both sides of the creek. Much of the area—probably more than one-half—is in grass, the remainder being about equally divided between corn and wheat. The country rock seems invariably a limestone, and the soil is light and porous. A small amount of timber is being cut on the hills rimming the basin, being worked by a number of small mills on the spot.

WIDNER CREEK.

Widner Creek joins the South Fork about 2 miles above the mouth of Rosenbaums Creek, and though the area drained by it seems to be slightly larger than that drained by the latter creek, and a larger proportion of the basin is said to be forested, the discharge was very much less, being inappreciable at the mouth, the only place where the stream could be seen.

RUSH CREEK.

Rush Creek, the next tributary, enters the South Fork about 2 miles south of the village of Friendship, and is a slightly larger stream than either of the last two described. The area drained is very rough and mountainous, and is about two-thirds forest covered. At the time it was visited, on October 2, it was carrying 2 second-feet, and was said to be at its lowest known stage. Its flood stage is about 3 feet higher.

MILL CREEK.

Mill Creek, the largest and most important tributary entering the South Fork along this part of its course, was gaged about a mile above its mouth, the only place where the stream could be reached, and on July 27 was carrying 18 second-feet and on the 2d of October 13.03 second-feet. The drainage basin is inaccessible and was not visited. Residents of the locality state that with the exception of a narrow strip along the creek not far from the river the basin is very rough, rugged, and steep, and is entirely forest covered. Much less than one-third of the total area is cleared land. There are a number of large springs in the basin. The stream was stated to be at its extreme low-water flow at the time of the October visit, when it was carrying 13.03 second-feet. The average flood rise is about 4 feet, although in some cases it has been as great as 5 and 6 feet.

GROSE CREEK.

Grose Creek is a small branch which was carrying 2 second-feet on July 27, but was almost dry at the time of the October visit. Its drainage basin seems to differ in no way from those of the streams entering below it.

ST. CLAIR CREEK.

St. Clair Creek drains perhaps a larger proportion of cleared land than any other stream in this vicinity, all the land along it being cleared to the foot of the mountains, but probably four-fifths of the entire basin is in forest. This stream was measured near its mouth at time of extreme low water, on October 2, and was carrying 2 second-feet. The rise during floods is about 4 feet.

Considering as a whole the area drained by Widner, Rush, Grose, and St. Clair creeks, it is very rough and mountainous, with steep, forested slopes, the small proportion of arable land, which amounts to less than one-fifth of the area, being confined to narrow strips bordering the creeks and immediately along the river.

WEDSTONE CREEK.

Wedstone Creek enters the river from the south, at Holstein Mills, and at the time it was visited it was carrying a quantity of water too small to even be estimated. Its extreme flood height is about 3 feet above its low-water stage. Its drainage area is largely cleared land, the forested portion being less than that of any of the other basins mentioned and estimated to be about one-third.

HOGTROUGH CREEK.

Hogtrough Creek, the next tributary above, was also too small to measure at the time of the September visit, carrying about 0.5 second-foot (estimated), which is probably the minimum flow. The flood

height is about 3 feet. The area drained is for the most part rough and steep, and the proportion of cleared land is very small, being confined entirely, so far as could be ascertained, to the first 2½ or 3 miles above its mouth and to tracts lying within 200 or 300 yards of the stream.

There are two small mills on the creek, the first one about 100 yards above its mouth, being a small sawmill and gristmill known as Pierce's mill. The power is obtained from a 16-foot overshot wheel with 4 feet face. The mill operates only one pair of stones, grinding for toll only, and saws an extremely small amount of lumber. About a mile above the mouth of the creek is a small mill operating one pair of stones by a 16-foot overshot wheel, but the name of the owner was not ascertained, nor any data regarding the power developed.

POMER CREEK.

Pomer Creek is the largest tributary to the South Fork in this part of its course. It drains an area rougher and steeper than any of those yet described, and one containing a smaller proportion of cleared land. The cleared area is confined to a narrow strip along the stream close to its mouth. There are no mills on the creek, so far as could be ascertained, though about a mile above its mouth there are evidences of a mill, which was probably washed away by one of the freshets to which the stream is subject. This creek reached its minimum flow in the fall of 1900. It was measured on October 1, when the discharge was 5 second-feet. The flood rise is about 4 feet. The amount of water carried during floods is very great.

This was the last tributary investigated, as the river was not followed much above the Rye Valley, and was too small at this point to be of value for water-power purposes. There is but little scenery worthy the name to be found over the larger part of this area, most of the country presenting a very quiet, pastoral type of beauty.

MIDDLE FORK OF HOLSTON RIVER.

PHYSICAL FEATURES.

The Middle Fork rises a little to the south of the village of Old Mount Airy, Va., on the western slope of the Blue Ridge, in the valley between Walker Mountain on the north and the Brushy Mountains on the south, and flows in a direction generally parallel to the course of the South Fork until a few miles above the junction, where it turns to the southwest. Below the junction the stream continues its general southwesterly course, and after being joined by the Watauga it unites with the North Fork of Holston River, near the town of Kingsport, Tenn., forming Holston River, which is in turn joined by the Nolichucky and the French Broad and finally unites its waters with those of the Little Tennessee, forming a system which drains southeastern Virginia, western North Carolina (excepting a small portion the waters from which flow into the New river system),

eastern Tennessee, northern Georgia, and northern Alabama. That part of the area lying in the basin of the South Fork is mapped on the Roan Mountain, Bristol, Abingdon, and Wytheville atlas sheets of the Geological Survey. The area drained by the Middle Fork lies mostly to the north of the river, the distance from the summit of the ridge dividing its watershed from that of the South Fork to the stream being too small to admit of the formation of streams of considerable size. The general character of the country is similar to that of the area drained by the South Fork below the junction, the topography consisting of small and rounded hills and ridges, grass covered to the top, with very gentle slopes and with low divides between the small creek watersheds. By far the larger part of the area is cleared land, the woodland amounting to probably less than 10 per cent for that part of the basin lying between the junction and the mouth of Bear Creek. Above that point the valley becomes very narrow, being constricted between the slopes of the two peaks forming the Brushy Mountains, which are in a large measure wooded. Throughout the remainder of the basin the wooded areas are mostly in the form of small groves or tracts of a few acres. The soil is seemingly very fertile and is light and porous, though some areas of clay were found. Limestone is the country rock, and the bed of the river is also in that stone. The area drained by the Middle Fork constitutes the finest and most prosperous farming and stock-raising country seen during the whole investigation, and the lands are held at a high valuation.

DISCHARGE MEASUREMENTS.

During the investigation a number of measurements were made of the flow of this stream and of its principal tributaries. The measurements made on the Middle Fork are given in the following table, those made on its tributaries are given in the table on page 73.

Discharge measurements of Middle Fork of Holston River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-ft.*
July 25	Sevenmile Ford, Va	L. V. Branch	13.00	71.23
Do	Above mouth of Bear Creek, Virginia	do	6.23	18.00
Oct. 1	do	do	7.69	11.00
July 24	Five miles above mouth, Virginia	E. W. Myers	5.96	172.00
Sept. 28	do	do	6.21	100.00

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

WATER POWERS.

For 100 yards above the junction with the South Fork there is a fall of about 8 feet in 100 yards, as near as could be ascertained, over a very rough and rocky bed formed by ledges of limestone crossing the

river at right angles. High and steep bluffs rise from the water's edge on both sides of the stream, and from them large quantities of limestone could be quarried. A railroad crosses the stream just below the shoals, and would afford ample transportation facilities. This locality would repay an investigation by anyone desiring power in this section.

About 2½ miles above the mouth of the stream there is a fall known as Big Shoals, where the river is divided by several islands, the largest of which is about an eighth of a mile long. In one-fourth of a mile, as near as could be estimated, there is a fall of 10 feet, determined by hand level and aneroid, and near the head of the shoals there is a fall of about 4 feet in a distance of 100 feet, and an abrupt descent of about 3 feet at the foot over a rock ledge crossing the stream at right angles. On the south side of the river broad bottoms extend the length of the shoals, but on the north side the banks are high and bluffy. The country rock close to the river seems to be slate of two varieties, one hard and black, the other soft and either yellow or gray. Limestone occurs in small quantities close to the stream, but it forms the predominating rock of the uplands.

From the mouth of Hogthief Creek to De Busk's mill the river is a placid stream, with very little fall. The rock is a limestone which quarries well, and almost all of the country, which is very rolling, seems to be cleared. At De Busk's mill there is no race, a wooden flume taking the water from the forebay to the wheels. The dam is a timber structure planked on the upstream face, 10 feet high and 168 feet long, backing the water about 2 miles. The mill is a sawmill, but it also contains wood-working machinery. It is operated by a 36-inch turbine rated at 30 horsepower under 9½ feet head, and has a capacity of 5,000 feet of lumber per day. At this site there is also a wheat mill with a capacity of 30 barrels per day, consisting of three double stands of rolls operated by a 20-inch Success turbine rated at 25 horsepower. The corn and feed mill is operated by a homemade wheel yielding about 4 horsepower. Sometimes during very dry seasons when all of the machinery of the mill is in operation at the same time the whole flow of the stream is required, as the dam is somewhat leaky, and at times the pond has been drawn down 1 foot during a day's run.

Above the De Busk mill and as far up the stream as Chilhowie there is very little fall in the river, and what there is is very well distributed, there being no noticeable concentration at any place. There are localities, however, where dams from 10 to 15 feet high could be built, but in every case the fall obtained would be that due to the dam, and the flooding of valuable lands above would prohibit the construction. The bottoms are very broad and lie only a few feet above the level of the river. The river receives practically no drainage throughout this part of its course, one stream only, Huttons Branch, being large enough to gage. The country rock is a limestone, and the land is practically all cleared and is given over to stock raising and to grain.

Above Chilhowie and as far as Sevenmile Ford there is no concentration of fall in the stream, and the country preserves the same general character, except that the bottoms begin to grow narrower and the hills to close in on the river and to rise higher and more sharply, the country presenting a much more broken appearance. The area is not so largely cleared, there being probably 25 per cent of woodland in this section. The stream has an extreme rise of 12 feet in this part of its course. At present there is no mineral industry hereabouts, though several years ago much baryta was mined, but practically all has been taken out that can be worked at a profit.

Glenn's mill is the first mill on the river above the De Busk mill. It is just above the mouth of Byars Creek, and is a combined gristmill and sawmill having a capacity of 40 barrels of flour per twenty-four hours, and, with three choppers, requiring about 46 horsepower. The total power development here is 64 horsepower. The wheels are homemade, center discharge, built on the turbine plan, and of 20, 16, 10, and 6 horsepower, respectively. The sawmill contains one sash saw requiring for its operation about 12 horsepower. The dam is of timber frames planked over, and is 11½ feet high and 120 feet long, giving a working head of 11 feet at the mill and backing water about three-fourths of a mile. It is stated that there is always sufficient water to operate all of the machinery in this mill at the same time, though the dam is somewhat leaky.

The next power on the stream is about one-fourth of a mile below the town of Marion and is owned by Messrs. Look & Lincoln, who state that a fall of 10 feet can be obtained by building a dam of that height, and that no arable land would be flooded.

Look & Lincoln's mill, the next power above, is in the lower end of the town of Marion. Wagons, plow handles, and wagon materials are manufactured. There are two dams, the upper one of stone for half its length and of wood for the remainder, 9½ feet high and 110 feet long, the water being turned directly into a 33-inch Success turbine developing about 30 horsepower. It is estimated that with this fall from 40 to 45 horsepower can be obtained the year round. Just below this dam the river makes a very abrupt bend, and about 150 yards below the upper dam, if the course of the river be followed, or 40 yards in a straight line, is the lower dam, belonging to the same firm. This dam is 8 feet high and 100 feet long, made of timber frames planked over, and backs the water to the foot of the upper dam. The water is led direct to a 36-inch turbine yielding about 20 horsepower, which is used occasionally to operate two sets of corn stones and a turning lathe. A steam engine of 100 horsepower is also used in the wagon-material department. The whole mill has a capacity of about 300 farm wagons annually and about 2,000 pairs of plow handles.

In the upper end of the town of Marion is Hull & Staley's mill, which has a capacity of 75 barrels of flour per day. The dam is one-fourth of a mile above the mill, and is of timber frames planked over.

It is 12 feet high and gives a head of 20 feet at the mill. There are two turbines, one a 30½-inch Leffel developing 32 horsepower, the other a 24-inch Success wheel developing 18 horsepower, and it is said that in seasons of low water the entire flow of the stream is necessary to operate the larger wheel.

About 3 miles above Marion is the Mount Carmel mill, a flouring mill with a capacity of 50 barrels per day, using about 32 horsepower, which is developed by two 30½-inch Leffel turbines working under a head of 9 feet. There is no race, the mill being built at the dam, which is new, of timber frames planked over, 9 feet high and 125 feet long, backing the water about 400 yards. The miller estimates that in the driest seasons there is in the stream only water sufficient to develop 16 horsepower with this head. He also stated that a portion of the water carried by the stream sinks into its bed between this mill and the town of Marion, but no evidence of this was seen.

There are no other mills or mill sites between the Mount Carmel mill and the mouth of Bear Creek, although the fall is considerable, and from the configuration of the country it seems probable that at a number of localities small amounts of power could be developed. The north side of the river is very steep and bluffy, and on the south side the bottoms are higher above the river level than at any other place along the stream. Considerable limestone has been quarried in this vicinity, the greater part of it going to the alkali works at Saltville, Va.

TRIBUTARIES OF MIDDLE FORK OF HOLSTON RIVER.

DISCHARGE MEASUREMENTS.

During the investigation the following measurements were made of the important tributaries of the Middle Fork:

Discharge measurements of tributaries of Middle Fork of Holston River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
July 24	Hogthief Creek	One-half mile above mouth, Virginia.	L. V. Branch	5.00	5.00
Sept. 29	do	do	E. W. Myers		5.00
Do	Cedar Creek	At mouth, Virginia	do		3.42
Do	Halls Creek	do	do	1.73	17.36
July 23	Huttons Branch	do	L. V. Branch	4.45	5.00
Sept. 29	do	do	E. W. Myers	4.43	5.00
July 25	Walker Creek	50 yards above mouth, Virginia	do	4.90	3.00
Sept. 29	do	do	do	4.89	9.00
July 25	Byars Creek	At mouth, Virginia	L. V. Branch	1.52	4.00
Sept. 29	do	do	E. W. Myers	1.58	2.24
July 25	Hungry Mother Creek.	Ford of main road from Marion, Va.	L. V. Branch	1.18	2.45
Oct. 1	do	do	E. W. Myers	1.17	2.36
July 25	Staleys Creek	Marion, Va	L. V. Branch	9.26	14.32
Do	Bear Creek	At mouth, Virginia	do	6.99	2.01
Oct. 1	do	do	E. W. Myers	6.90	3.00

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

Descriptions of the drainage basins and water powers of these tributary streams are given on the following pages.

HOGTHIEF CREEK.

The first tributary of the Middle Fork of sufficient importance to deserve mention is Hogthief or Sevenmile Creek, which enters the river from the north, at Moab, Va., and has a reported length of about 7 miles, although as measured on the map it is only about 4 miles long. The greater part of its drainage basin is cleared, the woodland amounting to probably not more than 5 per cent of the area. About half of the cleared land is in pasture, the remainder being about equally divided between corn and wheat. The whole basin is either flat or gently rolling, though it contains a few small hills, some of which are wooded to the top, but the hillside slopes are all very gentle. Limestone is the country rock of the area. When the stream was visited (first on July 24 and again on September 29) it was, according to all obtainable information, lower than ever before known. On both occasions it was discharging 5 second-feet. It is stated that the maximum rise is about 4 feet. This stream is now much more flashy in nature than it was several years ago, due no doubt to the deforestation of its headwaters which has taken place within the last few years. Not only do the floods rise with greater rapidity and to a greater height than formerly, but during the dry seasons the creek falls to much lower stages, despite the fact that it is fed by many large springs.

The first mill on the stream is Kendrick's mill, located about 100 yards above its mouth. This is a gristmill of two runs of stones, operated by a turbine 12 inches in diameter, which develops 20 horsepower under a head of 27 feet, though it is probable that 10 horsepower will operate all of the machinery in the mill. The dam is about 100 feet above the mill and is about 5 feet high and 25 feet long, built of timber frames planked over, and gives a very small pond. According to the statement of the miller the stream was never too low to run the mill until 1899, but it has been so, except at intervals, since that time, and he attributes it to the cutting away of the timber from the headwaters.

CEDAR CREEK.

The next tributary of the Middle Fork is Cedar Creek, which enters the river from the north, about 3 miles above the mouth of Hogthief Creek, which it seems to resemble in every respect. Practically all of the area drained by Cedar Creek is cleared land, which is used almost exclusively for grazing purposes. The meadows are broad and fertile, and the grass-covered uplands are nearly level. There are a few small hills, but they have very gentle slopes. It is possible that this stream may fall about one-tenth of a foot lower than its stage at the time it was visited (September 29), when it was discharging 3.42 second-feet. Its maximum rise is about 3 feet above its low-water mark.

HALLS CREEK.

Halls Creek, which enters the river a short distance below De Busk's mill, is a slightly larger stream than either Hogthief Creek or Cedar Creek, but the distinguishing characteristics of its drainage basin seem similar in every respect to those noted for the other creeks. It falls between 2 and 3 inches below its level at the time it was visited (September 29), when it was discharging 17.36 second-feet. During floods it rises between 3 and 4 feet.

HUTTONS BRANCH.

The next tributary is Huttons Branch, locally and more properly known as Huttons Creek. This stream rises on the southern slopes of Walker Mountain and drains a very small area of wooded land. The rest of the basin is cleared and is used almost exclusively for grazing, being quite level, with very broad bottoms and small, gentle hills. This stream was visited on July 23 and on September 29, and at both times was carrying 5 second-feet. Its high-water rise is 3 feet. There is one mill on the creek, operating a single pair of stones by means of a 16-foot overshot wheel and using a very small amount of power. The creek forks just below the site of the mill, the forks being at an angle of nearly 180 degrees, and the water from both branches is brought to the mill through a long wooden flume.

CHILHOWIE BRANCH AND CARLOCKS CREEK.

These are the only other streams in this section carrying an appreciable amount of water, and their discharge was much too small to admit of measurement.

WALKER CREEK.

Walker Creek, draining the southern slopes of Walker Mountain, is the next tributary of the Middle Fork. The upper part of its basin is rough and steep and is practically all in woodland, but immediately along the forks there are considerable areas of cleared land, and below them practically all of the basin is cleared. Over this lower part the topography is similar to that noted for the streams lying farther down in the drainage basin of the main stream, except that the hillside slopes are somewhat steeper and the hills a little less rounded. The creek is said to have attained its minimum stage of flow during the summer and fall of 1900. Its flood rise is about 4 feet. There are very valuable and extensive deposits of gypsum in this basin, but they have been very little or not at all worked.

BYARS CREEK.

This creek enters the Middle Fork from the south, about 4 miles below the town of Marion, Va., and is the first important tributary

rising in the area between the Middle and South forks. Considerable of the land in its basin is cleared and under cultivation or in grass. It is rather smooth and level, all of the slopes being gentle. Limestone is the country rock, and it has been quarried in large amounts for use in the alkali works at Saltville. During floods the creek rises about 3 feet at its mouth.

HUNGRY MOTHER CREEK.

The next tributary is Hungry Mother Creek, on the southern slopes of Walker Mountain. The upper part of its basin is a very rough and rugged country of extremely steep slopes, containing a small proportion of cleared land. In the lower part of the basin the country is much more broken than that of the basin of any tributary of the Middle Fork yet described, the hills rising sharply from the stream to considerable heights, and the uplands, which downstream were a plain, consisting of small and rugged hills, seemingly not more than half cleared. In this part of its course the valley of the creek is very narrow. Most of the cleared land is in grass, the remainder being cultivated in wheat; and although much of the area near the mouth is still in woodland, it seems probable that these areas are too small to have very great effect on the run-off. The soil seems shallow, and there is much exposed rock over the basin, all of it seemingly a limestone formation. The floods on this stream are violent, the creek rising 5 feet in a very short time, but the periods of high water are of short duration, owing to the great slope of the stream channel and the steepness of the hillsides over the basin.

STALEYS CREEK.

Staleys Creek, entering the river from the south, within the limits of the town of Marion, Va., is the next tributary. The valley of this stream so far as seen was very largely cleared, probably 50 per cent or more. The lower part of the basin is rolling and grass covered, but the upper part consists of the northern and eastern slopes of the Pond and the Brushy mountains, and is rough, broken, and mountainous, the slopes being very steep and forest covered. The lower part of the basin is in a limestone formation, but the slopes of the mountains are of sandstone. About 4 miles from Marion, in the valley of this stream, is an iron mine owned by Mr. J. L. Woodruff, of Marion, from which about 100 tons of ore are shipped daily to the furnace at Pulaski, Tenn.

The fall of the stream is considerable and it is more largely used for power purposes than any stream of its size in the region. The first fall is known as the Old Foundry site. A fall of 17 feet can be obtained at this place, yielding about 20 horsepower. The site is now unoccupied, but a small wagon factory is to be built at an early date.

About one-fourth of a mile above the Old Foundry site and practically one-fourth of a mile above the mouth of the creek is Seaver's planing mill, where the fall is 18 feet, and it is said that 18 horsepower is developed by one 18-inch Success turbine. The race is a plank flume 1,400 feet long, and there is practically no dam, only a slight obstruction, just sufficient to turn aside the water of the creek. The mill contains wood-working machinery and a gristmill, and it is said that the stream does not at all times furnish power sufficient to develop the horsepower stated, occasionally falling so low as to yield only about 9 horsepower with 18-foot fall.

Atkins Brothers' mill is 4 miles above the Seaver mill and manufactures spokes, hubs, pick handles, etc., and saws walnut timber for export. It uses about 18 horsepower, developed by an 18-inch Success turbine working under a head of 18 feet. There is a very slight dam, barely sufficient to turn the water aside. The water is led to the mill by a plank flume 200 feet long. This is the last mill on the creek.

BEAR CREEK.

Bear Creek, which enters the river from the north about 5 miles above Marion, Va., drains a part of the southern slopes of Walker Mountain and the northern slopes of the Brushy Mountains. The whole area is extremely rough and mountainous. Probably less than one-third of it is cleared land, the cleared areas being confined to the comparatively level land immediately along the stream and to some of the lower and more gentle slopes. The stream probably never falls lower than the point reached during July and August, 1900, when it was carrying about 2 second-feet. During floods it rises about 4 feet at the mouth. Some timber has been cut in the valley, and considerable quantities of tan bark are stripped and hauled to the railroad at Marion. There are no mills on this stream.

WATAUGA RIVER.

PHYSICAL FEATURES.

Watauga River rises on the northern and eastern slopes of Grandfather Mountain, on the southern boundary of Watauga County, N. C., and after flowing about 6 miles in a northeasterly direction is joined by Boone Fork, a stream which rises on the eastern slope of Grandfather Mountain and flows first due east about 4 miles and then to the north about 4 miles, or to its junction with the Watauga. At the junction the river changes its course to the northwest, and with many bends, rapids, and falls flows through Watauga County, N. C., and Johnson and Carter counties, Tenn., uniting its waters with those of the South Fork of Holston River about 9 miles northwest of Johnson City. In its course it is joined by many tributaries. It drains an extensive area, a large part of which lies in the

high mountains. The basin to the west of Carter, Tenn., was not examined, being well out of the mountains and of the same general character as the valley of Holston River already described. For convenience the basin has been divided into three parts, which are differentiated by very well marked physical characteristics. The divisions are: (1) The area lying to the west of the Iron Mountains on the north side of the river; (2) the area lying to the east of the Iron Mountains; and (3) the area lying to the west of the Iron Mountains on the south side of the river.

AREA LYING TO THE WEST OF THE IRON MOUNTAINS ON THE SOUTH SIDE OF THE RIVER.

This portion of the drainage basin of Watauga River comprises the areas drained by Gap Creek, Powder Branch, Buffalo Creek, Sinking Creek, and Brush Creek and is some distance from the mountains. As a consequence it is much less rugged than the country farther to the east, is better adapted to agriculture, and a great part of the land is cleared, hay being the principal product, though much corn and wheat are grown. Most of the area drained by these streams is either level or very gently rolling, and over the greater part of it probably about 90 per cent of the land is cleared, the woodland being confined to the tops of some of the higher hills and to small and isolated areas on the lower but less fertile tracts. Of the total area drained by these streams probably more than 75 per cent is cleared. The soil is deep and fertile and the country rock is without exception a limestone.

One of the peculiar features of this area is the large number of small closed drainage basins, or sinks, which have been noted in other watersheds of the region and which here occur in the nearly level uplands dividing the basins of the various small creeks. These sinks are particularly noticeable for their size and number near Milligan, Tenn., at which place occur the largest seen during the whole investigation, one of them covering an area estimated at 10 acres and having a large pool of water in its bottom. This locality is the only one, however, over the whole area drained by Watauga River in which these basins occur.

AREA LYING TO THE WEST OF THE IRON MOUNTAINS ON THE NORTH SIDE OF THE RIVER.

This portion of the basin includes the valley of Lick Creek, the areas drained by several small branches, the large valley drained by Stony Creek, and a part of the high and rugged area covered by the Holston Mountains. The latter, however, from its character more properly belongs to the area lying to the east of the Iron Mountains.

For perhaps a half mile or a little more to the north of the river, near Carter, the country is very hilly and rough, with steep slopes, and is largely wooded. It changes gradually as the level of the

uplands is reached and becomes gently rolling, being composed of large and broad swells or ridges and low, flattened hills rising from 25 to 30 feet above the level of the valleys between them, the valleys being generally broad areas of level land. The hillside slopes are very gentle, ranging from 5 to 10 degrees. About 75 per cent of the area appears to be cleared, about half of the cleared land being grass covered.

Limestone is the country rock, as on the south side of the river, but very little is seen exposed. The soil is deep and fertile, that in the immediate valleys of the creeks being largely alluvial, while on the uplands it is gray or yellow in color and loose and porous in character.

The forest growth, which is pine, oak, and chestnut, is in small areas, which as a rule are too widely separated to have much effect on the run-off.

The country immediately along the river from Carter to the town of Watauga Valley is much broken by a number of large hills, which are much steeper than those heretofore observed, but just above the latter place these recede from the river, leaving the general appearance of the topography similar to that noted on the south side of the stream, though a little more broken and rough. The hills are the outliers of the Holston Mountains, and are covered with a dense forest growth.

Near Elizabethton the bottom lands are very broad and fertile, extending up the river as far as the mouth of Stony Creek. The valley of the latter stream is of considerable width. Immediately along the creek and on the first bench or terrace the cleared land forms a large portion of the area, but with this exception the basin is in forest. The cleared land is said to amount to from 10 to 12½ per cent of the whole, this being all that is fit for cultivation, on account of the steepness of the slopes, the mountains rising very sharply from the valleys. They all are heavily timbered, little lumbering having been done in this area.

AREA LYING TO THE EAST OF THE IRON MOUNTAINS.

This part of the drainage basin of Watauga River differs very greatly from the areas just described, being rough, rugged, steep, and mountainous, containing a very small proportion of cleared and cultivated or cultivable land, being largely covered with the original forest growth, which is rank, dense, and luxuriant.

As the river is ascended the limestone, which was the country rock over the areas just described, gives place to slates, shales, schists, and sandstones, and these in turn to granites and gneisses, which form the country rocks over all of the basin in North Carolina. Away from the river the land seems to be about one-fourth cleared, but instead of the deep and fertile surface covering seen before the soil is shallow and in many places is full of rock fragments, often angular, sometimes rounded as if waterworn, and in many places a stratum of these

fragments 2 or 3 feet beneath the surface is seen exposed in the banks by the roadsides.

Toward the North Carolina line the amount of cleared land diminishes greatly, the mountains rising too steeply from the water's edge to admit of clearing. As the river is ascended the valley narrows and the mountains rise to greater heights, often showing precipitous walls of bare rock several hundred feet high, forming a chasm known as the gorge of the Watauga. An occasional small clearing may be found on the slopes back from the river, where the country is less rugged, and on these settlers try to wring a scanty subsistence from the stony soil; but as a rule the mountains are forested to the top, though occasionally an undue amount of exposed rock on the slopes renders the growth sparse and stunted.

Within the gorge of the Watauga there is no room for a road and barely space enough for the stream. The channel is very rough and broken by many rapids and sudden falls, and the water rushes along with great velocity. In the 8 miles through which the gorge may be said to extend the average fall is about 65 feet to the mile, and in many places it is much more concentrated, one notable locality being near the State line, where there is a straight plunge of 10 or 12 feet, known as the Falls of the Watauga.

Upstream from the gorge the mountains rise to less heights, the valley broadens slightly, and the uplands back from the river are suitable for agriculture on a small scale. They are partially cleared and cultivated in grass or grain in the places where the hillside slopes are not greater than 20 or 30 degrees. The hills do not recede far enough to permit the formation of bottoms until the broad strip of level land known as Valle Cruces is reached. A short distance above this the gorge is redeveloped, though in a lesser degree, and there is very little cleared land directly along the river until Shulls Mill is reached. There are small areas of cleared land up some of the tributaries, however, also along the river between Shulls Mill and Foscoe, so that it is estimated that of the total area drained by the river above the North Carolina line about one-third is cleared land; but after an inspection of the basin this estimate seems too great. Above Shulls Mill the Watauga has a length of from 5 to 6 miles, measured in a straight line, and drains an area of which a large part is well suited to agriculture, being in the form of broad and fertile bottoms and terrace lands lying close to the stream. About 4 miles above the mouth of the Boone Fork, however, the slopes of Grandfather Mountain on the north and of Hanging Rock on the south close in on the river and the amount of arable land becomes very small, the cleared land being about one-fourth or one-fifth of the whole area above the junction of the Boone Fork. The soil of the bottoms is deep and fertile, being largely a black alluvium, but that of the hillsides is often shallow and full of angular fragments of broken stone, and is not very productive.

The portion of the basin in North Carolina lies in Watauga County, which occupies the entire breadth of the very elevated mountain plateau between the Blue Ridge and the Unaka mountains. It is traversed in a northerly direction by two massive cross chains connecting these two great ranges, viz, the Rich Mountains and the chain of which Grandfather Mountain may be taken as the starting point and Hanging Rock and the Beech Mountains as the prominent peaks, the basin of the Watauga lying to the west of the Rich Mountains. The surface of the whole country is very rough and rugged and has an average elevation of about 5,000 feet above sea level. The stream valleys are as a rule very narrow, but at intervals there are considerable stretches of bottom lands. The soil is generally a stiff gray or yellow loam, producing grains and grasses in abundance. Cattle raising is an important industry. Along the headwaters of the stream there is much alluvial soil in the creek bottoms and a great deal of vegetable mold on the mountain slopes, while on Banner Elk Creek and Elk Creek the bottoms assume the form of peaty bogs, which are very deep and retain the water draining into them from the mountain slopes for a long time, feeding it out to the streams gradually.

SCENERY.

All of the area drained by the Watauga in North Carolina lies in the high mountains, and the scenery is wild and picturesque, the exact opposite of that along the lower part of the stream or on the Holston, which is quiet and pastoral. Many beautiful mountain views are to be obtained, with quick-changing cloud shadows and with wisps of filmy clouds clinging about the summits, but the valleys are so narrow and so tortuous that it is seldom a view can be obtained from a sufficient distance to give its full beauty, although there are places near the gaps and on the divides where may be seen views approaching in grandeur any that the mountains afford.

The rugged beauty of the whole area finds its culmination in the massive bulk of Grandfather Mountain, which rises to a height of 5,964 feet, far above any peak in the vicinity, and is probably the most massive, wild, and rugged of the peaks of the Southern Appalachians. Though by no means the highest peak in the range, it so towers above its surroundings that one of the most extensive views in North Carolina can be obtained from its summit. From certain directions and in clear weather the summit of this mountain is seen to form the profile of an old man—hence the name—but this is seldom visible, for this grandfather of mountains keeps his face almost perpetually veiled in the clouds.

RAINFALL.

Like all other drainage basins throughout this region, the basin of the Watauga is subject to a very heavy annual rainfall, being greater

near the headwaters, where Grandfather Mountain causes an almost constant precipitation. This rainfall at times comes in the form of violent rain storms, but these are infrequent, the precipitation being well distributed throughout the year, though the summer rainfall is the greatest in amount. At times the heavy rains are long continued, lasting a week or more, and the streams rise to great heights and do a vast amount of damage. It is said that the greatest flood known in this section of the country occurred in 1867, when there was a week of heavy rainfall, followed by a violent rain storm lasting twenty-four hours and seemingly extending over the whole basin. At Butler the river rose 18 feet above its low-water mark, washing away several houses and barns and totally destroying a great many acres of valuable bottom lands lying immediately along the river. Similar floods are reported to have occurred in the valley of Roan Creek in 1861 and in 1870. Droughts are infrequent, and as a rule are neither severe nor long continued, the drought of 1900 being the most severe within the memory of the inhabitants of the basin.

SPRINGS.

A marked feature of the region is the great number of springs, the discharge of which ranges from less than a gallon a minute up, several being of very large size. One of the larger springs is in the village of Allentown, Tenn. The spring basin is nearly 100 feet in diameter and has a discharge estimated at from 8 to 10 cubic feet per second. Another large spring is directly on the bank of the river, at the town of Fishspring. Here there are a number of small streams flowing from crevices in the rock, the aggregate volume being 7 or 8 cubic feet per second. The peculiar feature with reference to this spring—for which it and the town were named—is that in the autumn, when the water of the river begins to grow cold, a large number of fish, especially sun perch, come from the river and enter the basin of the larger spring—a cavern beneath the surface of the earth—where they spend the winter, returning to the river after spring opens and the river water is again warm. Twenty-one hundred fish were caught in one season by means of a trap placed at the mouth of this spring when the fish were returning to the river, and 165 have been caught in a single night, all being very fat. This indicates the existence of a body of water of considerable size beneath the surface of the earth. This supposition is borne out by the fact that about 40 feet from the river an area probably 25 feet square has sunk several feet within the last few years, and a hole has opened in about the center of the depression through which fish can in the winter be caught by means of a hook and line.

TIMBER.

There is a great deal of valuable timber still standing in the basin of the Watauga, only about one-third of the area being cleared and in

cultivation. The character of the timber varies as the stream is ascended, hard wood seeming the predominant growth along the lower part of the stream and its tributaries, but gradually giving place to pine, spruce, or hemlock. On the upper part of Laurel Creek and of the main stream, upon which the most extensive timbering operations have been carried on, the growth seems composed entirely of the latter trees, and the yield of timber is heavy. Evidences of extensive timbering are to be seen over almost the entire basin, the river at the time of both visits—one in the summer and the other in the fall—being full of logs waiting for a rise in the stream to carry them down to the mills. Numerous splash dams have been built on the tributaries and several on the river itself.

MINERALS.

Not many minerals or mineral localities are reported from this basin, the only place where mining rises to the dignity of an industry being at the famous iron mines at Cranberry, N. C., where is mined an iron which rivals in quality and purity the best Swedish ore. There are other deposits of iron ore in the basin, those on the upper part of Roan Creek and on Doe Mountain being perhaps the most noted. Formerly some copper was mined at Elk Knob, just beyond the eastern limits of the basin, but nothing has been done there for several years.

TRANSPORTATION.

The transportation facilities for the greater part of the basin are entirely inadequate. The East Tennessee and Western North Carolina Railroad, from Johnson City, Tenn., to Cranberry, N. C., furnishes an outlet for the products of that part of the basin, and the Virginia and Southwestern Railroad, from Bristol to Elizabethton and thence up Watauga River and Roan Creek, serves the northern part of the basin, but the whole area within North Carolina possesses no railroad, its facilities for transportation being limited to the country roads, which with the exception of the one paralleling the river are very poor, being steep, rough, and full of stones, so that it is impossible for a team to haul more than half a load over them. It is thought, however, that this condition will soon be bettered by the construction of a railroad from Lenoir, N. C., to Blowing Rock, and thence across the basin, probably following the course of the river a considerable distance and connecting with other roads, either at Cranberry, Butler, or Mountain City. Watauga County has recently authorized a bond issue of $100,000 to aid in the construction of this road.

DISCHARGE MEASUREMENTS.

During the investigation a gaging station was established on Watauga River at Butler, Tenn., and on two of its tributaries—

Roan Creek at Butler, Tenn., and Elk Creek at Lineback, Tenn. The results of measurements at these stations, as well as of the numerous miscellaneous measurements on the river and its tributaries, are given herein; those made on the main river in the following table, and those on the tributaries in the table on page 85.

Discharge measurements of Watauga River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-ft.*
July 16	Elizabethton, Tenn	E. W. Myers	15.87	450
Aug. 2	do	L. V. Branch	15.77	593
Aug. 16	do	do	16.03	403
Oct. 5	do	E. W. Myers	16.03	348
Nov. 7	do	L. V. Branch	15.27	993
Dec. 28	do	E. W. Myers	15.68	533
Dec. 31	do	Ernest Graves	15.22	973
July 30	Butler, Tenn	E. W. Myers	1.37	434
Aug. 7	do	L. V. Branch	0.90	214
Aug. 17	do	do	0.84	166
Oct. 6	do	E. W. Myers	1.12	238
Nov. 7	do	L. V. Branch	2.20	591
Dec. 28	do	E. W. Myers	1.40	311
July 16	Watauga Falls, N. C	N. C. Curtis		79
Aug. 10	do	L. V. Branch	6.62	53
Oct. 7	do	E. W. Myers	6.52	60
Aug. 11	One mile above Shulls Mill, North Carolina.	L. V. Branch	4.05	19
Oct. 7	do	E. W. Myers	3.78	23

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table which were made at Butler, Tenn. In making the other measurements in the table, however, bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In those cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

WATER POWERS.

The fall of the Watauga River is very great throughout its length, and the selection of shoals for utilization would be largely a matter of convenience, the average fall of the stream in Tennessee being about 15 feet to the mile, and between Shulls Mill and the Tennessee line about 47 feet to the mile, with many short stretches where the fall is much greater. Very little of the vast power in this basin is utilized, however, either on the river or on its tributaries, there being, so far as could be ascertained, only three mills on the main stream, and these all small ones. The first mill is at Watauga Falls. It is a roller flour mill with a capacity of 30 barrels per twenty-four hours. The second one is just below the mouth of Cove Creek, where there is a fall of about 9 feet and a very good location for the construction of dams and buildings. Here there is a small sawmill and wagon shop which uses a small proportion of the water by means of a homemade tub wheel yielding an unknown amount of power.

The first shoal that could be developed into a power of considerable magnitude is just above the North Carolina line, where there is a fall of about 10½ feet, but it is in a deep gorge and at present is so inaccessible that it is of no importance as a power site.

For about 4 miles above this place, or as far as the mouth of Beech Creek, the concentration of fall is very great, and dams of almost any desired height could be built without excessive lengths across the top, and powers could be obtained limited only by the heights of the dams. There is a similar locality just below the mouth of the lower Laurel Creek.

Above this point and on through Valle Cruces there are a number of shoals in the river, but the average fall in the stream is less than that above or below, and since the bottoms are very broad and lie only a few feet above the water level, power could not advantageously be obtained in this part of the course of the river, on account of the flooding of valuable farming lands.

As has been stated, the gorge is redeveloped on a smaller scale a short distance above Valle Cruces, and the slope of the stream becomes very great, being a succession of rapids with large fall and many abrupt plunges. There are a number of places where a dam from 60 to 70 feet high could be built with stone quarried on the spot, while the level tops of the hills would afford a safe and excellent location for buildings; but until this country has made material advances and has provided means of transportation for raw materials and finished products, it is extremely improbable that any development of water power will be made beyond small amounts for purely local needs.

TRIBUTARIES OF WATAUGA RIVER.

DISCHARGE MEASUREMENTS.

During the investigation the following measurements were made of the tributaries of Watauga River, in order upstream:

Discharge measurements of tributaries of Watauga River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
July 19	Brush Creek	Near Carter, Tenn	L. V. Branch	6.77	10.03
Aug. 16	do	do	do	6.82	9.47
Sept. 24	do	do	E. W. Myers	6.94	5.14
Aug. 2	Sinking Creek	Lower ford of Johnson City-Elizabethton road, Tennessee.	L. V. Branch	3.73	5.0
Oct. 4	do	do	E. W. Myers	3.75	4.0
Aug. 2	Buffalo Creek	At mouth, Tennessee	L. V. Branch	5.85	20.0
Oct. 4	do	do	E. W. Myers	5.92	10.0
Aug. 2	Gap Creek	do	L. V. Branch	4.00	7.0
Oct. 4	do	do	E. W. Myers	4.12	3.0
Aug. 3	Laurel Fork of Doe River.	Allentown, Tenn	L. V. Branch	5.19	30.0
Aug. 17	do	do	do	5.50	15.0
Oct. 5	do	do	E. W. Myers	5.67	9.0
Dec. 29	do	do	do	5.05	27.0
Aug. 3	Little Doe River	do	L. V. Branch	4.42	35.0
Oct. 5	do	do	E. W. Myers	4.78	17.0
Dec. 29	do	do	do	4.30	28.3
Aug. 3	Wilson Creek	One mile above mouth, Tennessee	L. V. Branch	3.67	5.0
Do	Shell Creek	At mouth, Tennessee	do	2.35	14.0
Do	Doe River	Two miles below Roan Mountain, Tennessee.	do	8.46	41.3
Do	do	Near Allentown, Tenn	do	5.56	72.0
Aug. 18	do	do	do	5.81	50.0
Oct. 5	do	do	E. W. Myers	5.85	39.3
Aug. 2	do	Above Elizabethton, Tenn	L. V. Branch	5.94	143.4
Aug. 17	do	do	do	6.20	106.0

Discharge measurements of tributaries of Watauga River—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Oct. 5	Doe River	Above Elizabethton, Tenn	E. W. Myers	6.23	82.0
Dec. 31	do	do	Ernest Graves	5.23	304.0
Aug. 3	Stony Creek	One-half mile above mouth, Tennessee.	L. V. Branch	6.95	44.0
Oct. 5	do	do	E. W. Myers	7.59	16.0
Dec. 31	do	do	Ernest Graves	4.60	48.0
Aug. 13	Doe Creek	Ivyspring post-office, Tenn	L. V. Branch	5.94	9.0
July 30	do	Mouth of Doe (town), Tenn	E. W. Myers	5.23	59.0
Aug. 13	do	do	L. V. Branch	5.49	26.2
Oct. 9	do	do	E. W. Myers	5.46	28.38
July 30	Mill Creek	At mouth, Tennessee	do	9.48	15.0
July 29	Town Creek	At Shoun Crossroads, Tenn	L. V. Branch	3.48	29.2
Aug. 13	do	do	do	3.82	6.0
Do	Forge Creek	Near mouth, Tennessee	do	4.53	7.0
July 30	Roan Creek	Butler, Tenn	E. W. Myers	1.47	137.0
Aug. 7	do	do	do	1.02	65.0
Aug. 17	do	do	do	0.85	58.0
Oct. 6	do	do	do	0.86	52.0
Nov. 7	do	do	do	1.50	171.0
Dec. 28	do	do	do	1.20	82.0
Aug. 13	do	Key Station, Tenn	L. V. Branch	4.85	5.2
July 30	do	Above mouth of Mill Creek, Tennessee.	E. W. Myers	5.70	60.3
Aug. 6	Dark Ridge Creek.	One-half mile above mouth, Tennessee.	L. V. Branch	4.65	3.0
Do	Little Elk Creek	At mouth, North Carolina	do	1.20	6.0
Aug. 4	Blevins Creek	Cranberry, N. C	do	6.03	5.05
Do	Cranberry Creek	do	do	6.95	5.09
Aug. 12	North Fork of Elk Creek.	At Banners Elk, North Carolina	do	5.61	7.0
Oct. 8	do	do	E. W. Myers	5.64	4.0
Aug. 11	South Fork of Elk Creek.	do	L. V. Branch	11.96	9.38
Oct. 8	do	do	E. W. Myers	11.82	8.48
Aug. 9	Elk Creek	Lineback, Tenn	do	3.5	70.0
Aug. 17	do	do	do	3.5	56.0
Oct. 6	do	do	do	3.5	53.0
Aug. 6	do	One-half mile below mouth of the Little Elk, Tennessee.	L. V. Branch	7.21	64.0
Aug. 9	Big Dry Run	One-eighth mile above mouth, North Carolina.	do	1.55	0.85
Do	Fogey Creek	At mouth, North Carolina	do	2.94	1.4
Oct. 6	do	do	E. W. Myers	3.02	2.4
Aug. 9	Beech Creek	Above mouth of Fogey Creek, North Carolina.	L. V. Branch	5.6	7.3
Oct. 6	do	do	E. W. Myers	5.7	7.4
Aug. 9	Beaverdam Creek.	Near Leander, N. C	L. V. Branch	5.59	7.0
Oct. 6	do	do	E. W. Myers		8.0
Aug. 10	Laurel Creek (lower).	At mouth, North Carolina	L. V. Branch	10.62	4.0
Oct. 7	do	do	E. W. Myers		3.09
Aug. 12	Rockhouse Creek	do	L. V. Branch	2.17	16.3
Oct. 18	do	do	E. W. Myers		0.8
Aug. 12	Brushy Fork of Cove Creek.	do	L. V. Branch	2.06	5.19
Do	Cove Creek	Above mouth of Brushy Fork, North Carolina.	do	4.31	23.0
Aug. 10	do	At mouth, North Carolina	do	5.24	12.0
Oct. 7	do	do	E. W. Myers	5.15	14.0
Aug. 10	Dutch Creek	Valle Cruces, N. C	L. V. Branch	7.42	11.0
Oct. 7	do	do	E. W. Myers	7.37	6.0
Aug. 10	Laurel Creek (upper).	At mouth, North Carolina	L. V. Branch	2.62	10.0
Oct. 7	do	do	E. W. Myers	2.87	6.0
Aug. 11	Moody Mill Creek.	do	L. V. Branch	3.20	4.0
Aug. 10	Boone Fork of Watauga River	Shulls Mill, N. C	do	2.30	12.0
Oct. 7	do	do	E. W. Myers	2.11	13.0

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BRUSH CREEK.

The first tributary of the Watauga which was made the subject of investigation was Brush Creek, which rises near Johnson City, Tenn., and flowing in a general northwesterly direction joins the Watauga a short distance below Carter, Tenn., having a total length of between 7 and 8 miles and draining an extensive area. The drainage basin consists of large but low hills with very gentle slopes, largely grass covered. Probably 90 per cent of the area is cleared land, largely in pasture, but a small part is cultivated in corn and wheat. The soil is deep and fertile. The country rock is a limestone.

The creek has a fall of about 400 feet between Johnson City and its mouth. The water is used by two small mills, too small to be of importance, and there is no definite information concerning them at hand. It is probable that this creek reached its minimum stage in September, 1900, when it was discharging about 5 second-feet. During floods it rises about 3 feet above low-water mark at its mouth.

SINKING CREEK.

The upper or second Sinking Creek, which enters from the south, is the next tributary. It drains a narrow area between 10 and 11 miles long, about three-fourths of the lower part of which is cleared. Its headwaters drain the northwestern slopes of the Buffalo and the Cherokee mountains, a rough and rugged area, densely forested. The characteristics of soil and topography over the lower part of the basin are in every way similar to those of the basin of Brush Creek. The stream was very low at the time it was visited, early in October, attaining its lowest stage during that month. It was carrying 4 second-feet when measured on October 4. During floods it rises about 2 feet.

BUFFALO CREEK.

Buffalo Creek, the next tributary, drains a much larger area than either Brush Creek or Sinking Creek. The greater part of its drainage basin consists of low, flat, and rounded hills, for the most part grass covered. Probably from 85 to 90 per cent of the lower portion of the basin is cleared; but as the stream is ascended the country becomes more rugged, being very steep and mountainous near the headwaters, and is largely covered with forest, though it is probable that three-fourths of the entire area drained by the stream is cleared. It is in the basin of this stream that the great number of sinks which have heretofore been mentioned as occurring near Milligan are to be found. These sinks occur from Milligan to the east and southeast as far as Gap Creek. At the time of the fall visit (October 4, 1900) the stream had reached its lowest stage of flow (10 second-feet). Its maximum flood rise is about 3 feet.

Buffalo Creek has three small tributaries—Dry Creek, Toll Creek, and Powder Branch—all of which enter from the southeast.

GAP CREEK.

Gap Creek, the next tributary entering the Watauga from the south, has a drainage basin which seems in every way similar to that of Buffalo Creek, with the exception that no sinks were seen. This stream reached its minimum stage in the fall of 1900. When measured on October 4 it was discharging 3 second-feet. Its flood rise is about 3 feet at the mouth.

DOE RIVER.

The most important tributary received by Watauga River is Doe River, which rises in the high and mountainous area to the west and north of Roan High Knob, and flows in a general northerly and northwesterly direction, joining the Watauga at Elizabethton, Tenn. Near the mouth of the stream probably one-forth or more of the valley is cleared land, the cleared areas being the level bottom or terrace land immediately along the river; but about 2 miles above Elizabethton the gorge of the Doe begins, and from that point to Allentown the river flows in a very narrow channel carved out by its waters from the solid rock, which rises on either side in precipitous walls several hundred feet high. Near Allentown, where Doe River is joined by the Laurel Fork and Little Doe River, there is a considerable area of open and level arable land rimmed about by high and steep mountains. Above that place the gorge of the Doe becomes more pronounced, the sides rising higher and more steeply above the water, and the scenery, though confined, is very much grander than that of the lower gorge. A view in the upper gorge is shown in Pl. XXIII. Throughout the gorge the fall averages nearly or quite 100 feet to the mile, the greater part of it being in rapids; sudden plunges are rare. Power in large amounts could be obtained here. Above the gorge the fall averages about half as much, being about 50 feet to the mile.

The water power of Doe River is used at only two places. At Elizabethton water is taken from the stream above the town and is used in the operation of a small cotton mill and several small gristmills. A small woolen mill is also sometimes operated by power derived from the stream. The largest consumer of power was a woolen mill which was burned several years ago and has not been rebuilt. Near Roan Mountain Station there is a small lumber mill using three turbines working under a head of 12 feet, but the amount of power developed could not be ascertained.

Little Doe River.—This stream, which is tributary to Doe River at Allentown, drains an area in all respects similar to that drained by the main stream above the junction, being very mountainous and largely forest covered. So far as could be ascertained there is prac-

DOE RIVER VALLEY, TENNESSEE.

tically no cleared land above 2 miles from its mouth. None of the power of the river is utilized. The time of minimum flow was in September, 1900. The flood rise at the mouth is about 4 feet.

Laurel Fork.—The next important tributary of Doe River is the Laurel Fork, which joins it at Allentown, draining an area similar to that drained by the main stream and by the Little Doe. The Laurel Fork has a large fall and carries a considerable quantity of water, which is used at Allentown by a small sawmill, and just above that place by a combined sawmill and gristmill using a small amount of power and a fall of 16 feet. Another mill is reported farther upstream. It is stated that active lumbering operations are now in progress over the basin of the Laurel Fork and that much timber has been cut.

STONY CREEK.

The next tributary of the Watauga is Stony Creek, which enters the river from the northeast and drains a long and broad valley containing a larger proportion of cleared and cultivated land than either of the streams just described. The cleared land, however, is confined to the level bottoms bordering the creek and to the first bench or terrace—this being all that is susceptible of cultivation, so it is said—and amounts to only about one-eighth of the whole, the remainder of the basin being steep, rugged, and forest covered. At the time of the October visit the stream was said to have reached a point lower than ever before known. It was then carrying 16 second-feet. The high-water mark is about 6 feet above its level at that time.

The average fall of the stream is large, and its waters are used by several mills, all small, the first one being located close to the mouth of the creek and using a fall of 10 feet, the power developed being estimated at about 12 horsepower. The second mill is a short distance above and is a small corn mill operated by a homemade wheel developing an unknown amount of power. The third mill is about a mile above the mouth of the stream and is a small combined sawmill and gristmill using a small amount of power.

ROAN CREEK.

There is no other important tributary of the Watauga until Roan Creek is reached. The watershed of this stream, which joins the river at Butler, Tenn., is in the area between the Stone Mountains on the north and Snake Mountain on the south. The main stream rises near Snake Mountain and flows in a general northerly direction for 7 or 8 miles, when it is joined by Forge and Town creeks—streams which rise in the Stone Mountains and flow to the south—and turns to the southwest, flowing in that direction until its junction with the Watauga. In the latter portion of its course it receives one large tributary, Doe Creek. Roan Creek drains a very large area, known as Johnson County Cove, which has already been somewhat briefly

described (p. 38). The immediate valley of the creek contains practically all of the cleared land in its basin, though small areas have been cleared on some of its minor tributaries where the land is sufficiently level for cultivation. All of the timbered area is still in luxuriant forest growth, consisting principally of oak and chestnut, though maple, locust, pine, spruce, hemlock, poplar, and similar trees are found. Probably 75 per cent of the area is still wooded. Near the mouth of the stream the valley is very narrow and the proportion of cleared land seems smaller than farther toward the headwaters, where the basin bears a close resemblance to the country along the South and Middle forks of the Holston, being rather level and composed of low, grass-covered hills, which are largely cleared. The mountainous areas are high and steep, showing a great deal of exposed rock and being in places densely forested.

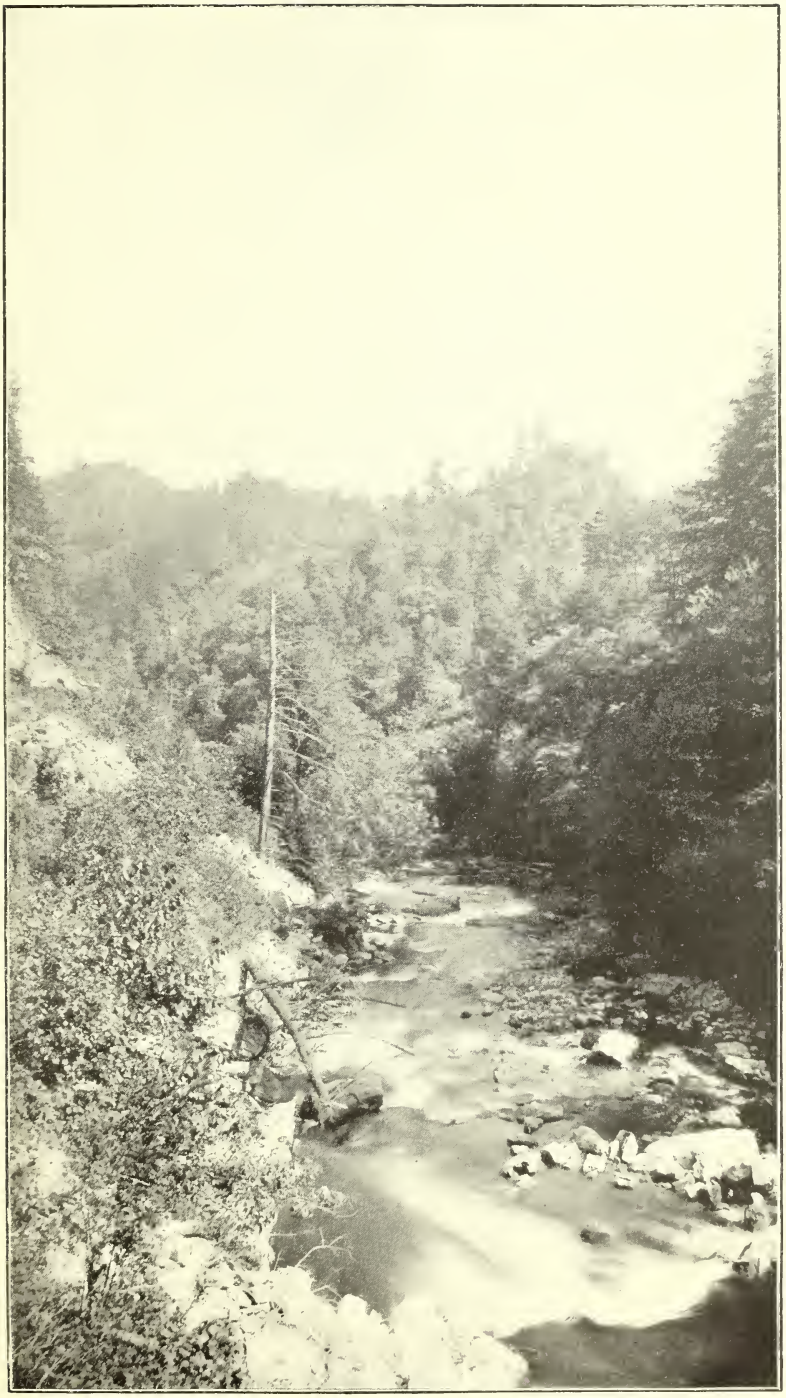
The fall of Roan Creek is considerable, being about 400 feet between the mouth of Doe Creek and a point about 2 miles below Mountain City, Tenn., a distance of 10 miles, making the average fall 40 feet to the mile. Between Shoun Crossroads and the mouth of Mill Creek, however, the fall is much less, and there are stretches where the current is very sluggish and the stream placid. The country rock is no longer a limestone—quartz rock, gneiss, and slate having made their appearance. Although this stream drains so large an area and has so great a fall its waters are used by very few mills.

The first mill on the stream is the roller flour mill operated by Cole & Scott, a short distance above Butler, which has a capacity of 30 barrels a day and is operated by a turbine working under a head of 12 feet. The next mill is 14 miles above Butler and is a combined gristmill and sawmill using a fall of 12 feet and a very small amount of power. The only other mill on the stream is Baker's gristmill, opposite Rhea Forge, where there is a fall of 18 feet.

Roan Creek reached its minimum stage during the fall of 1900. It was measured on August 13 and was carrying 5.2 second-feet. The average flood rise is about 5 feet, though there are records of a much higher rise in 1861 and in 1870, when the stream rose to a height of 8 feet.

Doe Creek.—This stream rises near Mountain City, Tenn., and flows in a direction generally parallel to the course of Roan Creek, from which it is separated by Doe Mountain, joining that stream about 6 miles above Butler. It drains a broad, flat valley which forms a part of Johnson County Cove, and furnishes more utilized power than Roan Creek, its waters being used for the operation of seven small mills.

Mill Creek.—Of the numerous small streams tributary to Roan Creek from the east and southeast none seen were of sufficient importance to justify gaging with the exception of Mill Creek, which enters from the southeast near Baker Gap. This creek was gaged near its mouth and its drainage basin was traversed from end to end. Near



ELK CREEK, NORTH CAROLINA.

ELK FALLS ON ELK CREEK, NORTH CAROLINA.

Roan Creek the proportion of cleared land is very small, but farther up the basin widens, and near the stream all the land has been cleared and is cultivated in corn and wheat or sodded in grass. The cleared land amounts to between one-fourth and one-third of the total area drained by the stream. About 100 yards above the mouth of the creek is Wilson's gristmill, a small mill containing two runs of stones, one for corn and one for wheat, the power necessary being developed by a 16-foot overshot wheel of about 30 inches face, yielding about 12 horsepower.

Town Creek.—This was the only other tributary of Roan Creek that was gaged. It was measured at Shoun Crossroads. There is one small mill on the creek containing two runs of stones, one for corn and one for wheat, and using 5 or 6 horsepower, which is developed by an undershot wheel.

ELK CREEK.

The next important tributary of Watauga River is Elk Creek (see Pl. XXIV), which rises at Banner Elk Creek, on the slopes of the mountain known as Hanging Rock, and flowing in a general direction a little north of west is joined near Elk Park by Cranberry Creek and Little Elk Creek, after which it turns to the north, entering Watauga River about 2 miles above Butler. A gaging station was established on this stream at Lineback, not far above the mouth, where daily readings of the stage of the water surface have been made.

The average fall per mile throughout its length is very great, the headwaters being at an elevation of about 4,000 feet above sea level. Near the mouth the fall seems to be less than the average, and there are large areas of cleared land and broad, level bottoms, from which, however, the wooded mountain slopes rise very sharply to considerable heights. There are small tracts of cleared land as far up the stream as Elk Mills. Between that place and the North Carolina line there is practically no clearing, but beyond the State line the country is more thickly settled and the areas of cleared land are more numerous. The latter are, however, of little importance compared to the total area of the drainage basin. No accurate estimate of the relative proportions of the wooded and cleared lands could be obtained, but it seems safe to say that the amount of clearing is less than 5 per cent of the area.

The amount of power along this stream is very great, but no attempts have been made to utilize it, and it seems improbable that efforts in that direction will be made for many years to come, unless some sawmill requires power to cut the timber which exists in such abundance over the basin. Perhaps the most noteworthy of the powers is Elk Falls (see Pl. XXV), where there is one of the most picturesque bits of scenery to be found in this country. Here there is a straight plunge of 26 or 28 feet, and in the first mile below it the

river falls 53 feet more, while in the 4 miles above it the fall averages 100 feet to the mile.

Above the latter point and as far as Banners Elk there are numerous shoals and rapids which would furnish small and compact powers with from 10 to 40 feet fall; but there is no demand for power in the present state of the country. Near the headwaters, and in particular near Banners Elk, the fall in the stream is very slight, the creek flowing through semimarshy areas and swampy meadows or peaty bogs covered with a dense growth of laurel, and the mountain slopes are covered with fine timber, spruce predominating, though many other varieties occur.

Throughout the basin the slopes are without exception steep, ranging as high as 50 degrees in some cases, and seem to be covered with a deep soil. The country rock over the lower part is a limestone, that of the upper part gneiss and quartz rock. The soil of the immediate valley is fertile and well adapted to agriculture, the principal crops being grass, corn, and wheat, with some buckwheat and sorghum cane. Many varieties of very fine apples are also grown.

The area being so largely forested the flow of the stream is large, the water never falling very low nor rising to great heights, and though the slopes are steep the high water lasts several days. The creek rises about 5 feet at the mouth.

The famous iron mills at Cranberry are located within the basin of this stream.

BEECH CREEK.

The next stream tributary to the Watauga is Beech Creek, which rises on the northern slopes of Beech Mountain, at an elevation of about 5,000 feet, and flows in a general northwesterly direction, joining the river about 4 miles above the State line. It drains a considerable area of steep, high, and densely forested mountain slopes, a very small proportion of the land being cleared. The cleared areas are confined exclusively to a small tract in the basin of Fogey Creek, which joins Beech Creek a short distance above its mouth, and to some of the narrow bottoms and small hills along the main stream for 2 or 3 miles above its mouth. The total area cleared amounts to possibly 5 per cent of the whole basin. Near the mouth of the stream the country rock seems to be a very good quality of granite, but as the creek is ascended this soon gives place to gneiss. The stream never falls very low, and during high water it rises about 4 feet at the mouth, that being the elevation of the highest mark that was found.

BEAVERDAM CREEK.

Beaverdam Creek, the next tributary entering from the north, rises near Baker Gap and Locust Gap, and flowing in a general southeasterly direction joins the Watauga just to the west of the small mountain known as Dyer Knob. For a mile or more above its mouth this

stream is in a deep gorge, the sides, which are very steep, rough, and rocky, and entirely wooded, rising from the water's edge. The fall of the stream in this gorge is considerable. None of it, however, is now used, but the remains of an old mill are to be seen. In this section and for some distance above Leander active timbering operations are now in progress, but so far very little timber seems to have been cut. Above this the valley widens, the hills are lower and the slopes less steep, and much of the land is cleared and under cultivation in grass or grain. On the fork which rises near Baker Gap almost all of the land is cleared except the tops of the hills and probably one-half or more of the country drained by the other forks. Of the total area drained by Beaverdam Creek probably one-half is cleared land, with a deep and fertile soil. The stream attained its minimum flow in the fall of 1900. The maximum rise at its mouth is about 4 feet.

LAUREL CREEK.

Laurel Creek is the next stream of importance to join the Watauga. It enters from the south, after draining a large basin. The creek valley is very rough and inaccessible for about 2 miles above its mouth, the gorge being deep and the sides in many cases sheer walls of rock. The fall in this distance is very great, being 600 or 700 feet. Above this the fall is much less, though it is still large, and a small part of the area has been cleared and placed under cultivation, the clearing being confined to the comparatively level lands lying near the stream and amounting to probably about 5 per cent of the whole basin. The hillside slopes are steep and forested and the soil is generally deep and fertile, although in some places it is shallow and full of rock fragments. Along the upper portions of the stream the soil is swampy in places and seemingly quite acid and in its present state unsuitable for cultivation.

Extensive lumbering operations have been begun in this basin and much timber has been cut on the hillsides, a great many logs being seen in the stream channel awaiting high water to carry them downstream.

It is said that this stream has never before reached a stage of flow as low as during the summer of 1900. The average flood height at the mouth is about 5 feet.

COVE CREEK.

Cove Creek, which enters the river from the north, is the principal tributary in this part of its course and one of the largest entering the stream. It rises near State Line Gap and flows in a general southerly direction for 14 or 15 miles, draining a broad and very fertile valley, which in comparison with the larger part of the watershed of Watauga River is thickly settled. It is estimated that about one-third or a little more of the basin is cleared land, largely in grass, as stock

raising is the principal industry throughout this country, as it is farther to the north. Throughout this valley, with the exception of the mountain slopes to the east and west, the hillside slopes are rather gentle—rarely reaching 30 degrees, the average being not more than 20 degrees—and the bottom lands are broad, with a deep and fertile soil. While the soil of the hillsides is less fertile, it produces very good crops of wheat and corn. From an agricultural standpoint the basin of this stream seems to be more valuable than any part of the watershed of the Watauga yet described.

At times the creek reaches a very low stage of flow, but never lower, it is said, than that attained during the summer and autumn of 1900. The average maximum rise at the mouth is about 5 feet; 6 feet is sometimes reached, and there is one report of a rise of 8 feet several years ago, probably when a destructive flood affected the entire basin of the river.

DUTCH CREEK.

Above Cove Creek the first tributary is Dutch Creek, which enters the river at Valle Cruces. This creek rises on the southern slopes of Hanging Rock and flows in a general northerly direction, draining an area which is very largely forest covered, containing not more than 20 per cent of cleared land, which is for the most part confined to the comparatively level land immediately along the creek. The mountain slopes are high, steep, and quite rugged, and are covered with the original dense forest growth. Like the other streams of the region, the creek reached its lowest stage during the summer of 1900. Its maximum rise at the mouth is from 3 to 4 feet.

LAUREL CREEK.

Laurel Creek is a small tributary entering the Watauga from the northeast, about 2 miles north of Shulls Mill. It drains a very small area, but carries a large quantity of water in comparison with the area drained, the basin being almost entirely forest covered. The cleared land is confined to a few small areas close to the river, these forming less than one-eighth of the basin. The hillside slopes are rugged, steep, and very rocky, and for the most part are covered with a dense forest growth. The stream reached its minimum flow during the summer of 1900. It rises 3 feet in its maximum floods.

BOONE FORK.

Immediately above Shulls Mill the Watauga is divided into two forks, the one to the east being known as the Boone Fork and the one to the west as Watauga River. The Boone Fork rises on the eastern slope of Grandfather Mountain and after flowing almost due east for 3 or 4 miles turns to the north and flows in that direction for about 4 miles, or to its junction with the main fork of the Watauga. There

are no roads along this stream, and its entire basin is inaccessible. The information that was gathered concerning it was obtained from persons dwelling in the country near by. The stream has a great fall, the headwaters rising at an elevation of about 5,000 feet, while the elevation at the junction with the Watauga is about 2,950 feet. Approximately 1,000 feet of this is concentrated in the first mile below the head of the stream, making the average fall per mile below that point between 165 and 170 feet. So far as could be learned none of the fall is used except by the Stonewall mill, a small sawmill and gristmill just above the junction with the Watauga. The sawmill is operated by a Leffel turbine yielding 15 horsepower under a head of 12 feet, which at low stages of the stream requires practically all of the water flowing. The gristmill is operated by three homemade center-discharge wheels working under the same head, but the amount of power given off by them could not be ascertained.

The entire area drained by the Boone Fork is high, rugged, and very mountainous, almost entirely covered with a dense and luxuriant forest growth. The soil is deep and porous, holding back the storm waters to some extent and feeding them out gradually to the stream, which has a large flow, never falling very low. Notwithstanding the great slope of the stream bed and of the hillside slopes, the floods are not so violent as would be expected.

In Part II of this paper, published as Water-Supply and Irrigation Paper No. 63, will be found descriptions of the drainage basins and water powers of the Nolichucky, the French Broad, the Saluda, the Broad, the Catawba, the Yadkin, the New, and other streams of the region.

[For index, see end of Part II, Water-Supply Paper No. 63.]

O

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, New York, to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground water," by F. H. King, and one on "Theoretical investigation of the motion of ground waters," by C. S. Slichter.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

1901.

Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part IV, Hydrography, 1901; octavo, 768 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton; and "The High Plains and their utilization," by W. D. Johnson.

Bulletins can be obtained only by prepayment of cost, as noted above. Money should be transmitted by postal money order or express order, payable to the Director of the United States Geological Survey. Postage stamps, checks, and drafts can not be accepted. Correspondence should be addressed to

The Director, United States Geological Survey, Washington, D. C.

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1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phoenix, Ariz., by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colo., by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.

15, 16. Operations at river stations, 1897, Parts I, II, 1898.

17. Irrigation near Bakersfield, Cal., by C. E. Grunsky, 1898.
18. Irrigation near Fresno, Cal., by C. E. Grunsky, 1898.
19. Irrigation near Merced, Cal., by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems of the Bighorn Mountains, by Elwood Mead, 1899.

24, 25. Water resources of the State of New York, Parts I, II, by G. W. Rafter, 1899.

26. Wells of southern Indiana (continuation of No. 21), by Frank Leverett, 1899.

27, 28. Operations at river stations, 1898, Parts I, II, 1899.

29. Wells and windmills in Nebraska, by Erwin Hinckley Barbour, 1899.
30. Water resources of the lower peninsula of Michigan, by Alfred C. Lane, 1899.
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35–39. Operations at river stations, 1899, Parts I–V, 1900.

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41, 42. The windmill: its efficiency and use, Parts I, II, by E. C. Murphy, 1901.

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45. Water storage on Cache Creek, California, by Albert E. Chandler, 1901.
46. Reconn. of Kern and Yuba rivers, Cal., by F. H. Olmsted and M. Manson, 1901.

47–52. Operations at river stations, 1900, Parts I–VI, 1901.

53, 54. Geology and water resources Nez Perce Co., Idaho, Pts. I, II, by I. C. Russell.

55. Geology and water resources of Yakima Co., Wash., by G. O. Smith, 1901.
56. Methods of stream measurement, 1901.
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58. Water storage on Kings River, California, by J. B. Lippincott, 1902.

59, 60. Development and application of water in southern California, Pts. I, II, by J. B. Lippincott, 1902.

61. Deep borings in United States, Part II, by N. H. Darton, 1902.

62, 63. Hydrography of Southern Appalachian region, Pts. I, II, by H. A. Pressey.

Other papers are in preparation. Provision has been made for printing these by the following clause in the sundry civil appropriation act for 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gaging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Stat. L., vol. 29, p. 453.]

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HYDROGRAPHY

OF THE

SOUTHERN APPALACHIAN MOUNTAIN REGION

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PART II

By HENRY ALBERT PRESSEY

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1902

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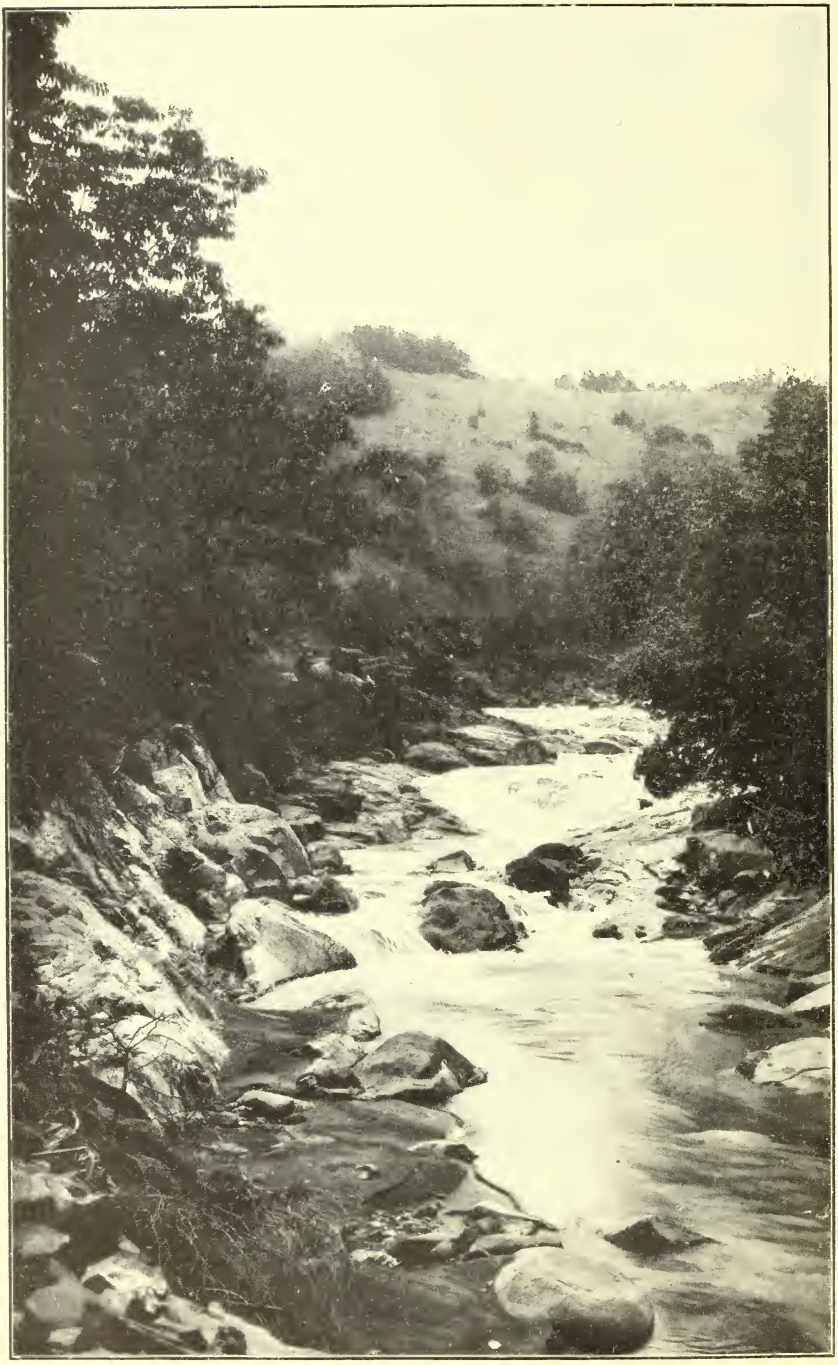


CANE CREEK, TRIBUTARY OF NOLICHUCKY RIVER, SHOWING CHARACTERISTIC ROCKY BED OF MOUNTAIN STREAMS.

HYDROGRAPHY OF THE SOUTHERN APPALACHIAN MOUNTAIN REGION.

PART II.

By Henry A. Pressey.

DRAINAGE BASINS—Continued.[a]

NOLICHUCKY RIVER.

PHYSICAL FEATURES.

This river is formed by the junction of Toe River and Caney River about 8 or 9 miles east of the Tennessee State line. Toe River is formed by the union of the North Toe and the South Toe between Sevenmile Ridge and the Burn Mountains. The area drained by the Nolichucky in North Carolina is in the high mountains within the limits of Yancey and Mitchell counties.

Yancey County is preeminently mountainous, the Black Mountains penetrating it from the southeast and extending to its center, or to near Burnsville. The great Unaka Range separates the county from Tennessee, and numerous cross chains intersect its surface in all directions, leaving very little valley land except along the banks of the streams. As elsewhere in the region, the mountains here are fertile to the top, being covered with a deep and friable soil which bears trees of great size, and where cultivated produces all of the grains and grasses, as well as very excellent fruits, the apples being especially fine. Cattle raising is an important industry.

Mitchell County lies between the Blue Ridge on the south and east and the Unakas on the north, and like Yancey County is very mountainous, there being little valley land except along the headwaters of Toe River. The cultivated lands are very fertile. All of the cereals grow well, grasses flourish, and fruits of very fine quality are produced in abundance.

The tributaries, like the main stream, rise near the summits of the mountain chains and flow over rocky and precipitious beds through narrow valleys. One of these rocky stream beds is shown in Pl. XXVI, a view of Cane Creek, one of the large tributaries of the Nolichucky.

[a] Continued from Part I, Water-Supply Paper No. 62.

The river first flows almost north for several miles, then turns toward the northwest and flows in a deep gorge through the Unaka Mountains (see Pl. XXVII) and into Tennessee, where preserving its general westerly direction it finally enters French Broad River about 7½ miles southeast of Morristown, draining a total area of 640 square miles above the Tennessee line, comprising almost all of Mitchell County and all of Yancey County. It leaves the mountains near Embreville, Tenn., which was the western limit of the investigation, although some observations were made of the character of the country lying to the west, sufficient to establish the fact that it differed in no important respects from the area already described as the Valley of East Tennessee.

None of the small closed drainage basins or sinks which are so numerous in the valley of the Holston were seen in the basin of the Nolichucky, but there seems to be a greater number of large springs.

RAINFALL.

The rainfall over the basin is about 51.2 inches per annum, 11.4 inches of which falls in the spring, 15.7 inches in the summer, 11.6 inches in the autumn, and 13.5 inches in the winter. The whole area is subject to sudden and violent rains, producing great floods, while in the winter the ice moving downstream sometimes forms ice dams which do a great deal of damage. The streams are therefore of much less value as sources of power than they otherwise would be. The effect of floods on the Nolichucky is shown in Pl. XXVIII.

FORESTS.

A very large part of the basin is still covered with the original forest. It is estimated that of the 640 square miles in North Carolina 78 per cent is forested, owing, doubtless, to the inaccessibility of the country. It is thought, however, that deforestation will begin in the near future, since in the summer of 1900 the Ohio River and Charleston Railroad was completed as far as the mouth of Caney River, and it is probable that the area drained by that stream will be lumbered at once, as already small spasmodic efforts in that direction have been made. Small sawmills run by water power have been built on a number of the smaller tributaries, and in a few instances splash dams have been constructed for the purpose of driving the logs over the rocky ledges of the mountain streams. Pl. XXIX, *A*, shows a splash dam on Little River, Tennessee, which raises the water 35 feet. Pl. XXIX, *B*, shows a characteristic combined sawmill and gristmill of Yancey County, with its immense overshot wheel.

MINERALS.

The area is very rich in minerals, Mitchell and Yancey counties, as already stated, furnishing a large part of the world's supply of mica. Many varieties of gems also occur, such as emerald, aquamarine,

GORGE OF NOLICHUCKY RIVER.

VIEW SHOWING EFFECT OF FLOODS ON NOLICHUCKY RIVER.

amethyst, and tourmaline. Some corundum has been found, and there are large deposits of iron ore, notably in the small stream valley of Bumpass Cove, where the iron is mined to supply the furnace at Embreville, which has a capacity of 150 tons of pig iron a day.

DISCHARGE MEASUREMENTS.

During the investigation a temporary gaging station was established on the Nolichucky near Chucky Valley, Tenn., where gage-height readings were maintained and measurements were made as shown in the following table. The river was also gaged near Erwin, Tenn., and numerous miscellaneous measurements were made on its tributaries, as shown by the table on pages 108 and 109.

Discharge measurements of Nolichucky River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-ft.*
Sept. 5	Near Chucky Valley, Tenn	L. V. Branch and E. W. Myers.	2.0	302
Sept. 20	do	do	2.18	442
Oct. 15	do	do	2.0	378
Nov. 10	do	do	2.9	919
Aug. 23	Near Erwin, Tenn	L. V. Branch	20.67	770
Sept. 4	do	do	21.53	411

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table which were made near Chucky Valley. In making the measurements near Erwin, however, bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In the latter cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

WATER POWERS.

The fall of the river is very much less than would naturally be expected in a stream draining so high and mountainous an area, the total fall between the junction of the North and South Toe and Embreville being only about 850 feet in a distance, following the course of the river, of about 40 miles, an average of about 21 feet to the mile. Throughout this part of its course the river flows through a gorge with steep and rocky sides, and although there are numerous places where dams could be constructed, and although the fall per mile is large, the opportunities for developing the power are meager, for building room is lacking and the construction of raceways would be costly. Good railroad facilities exist here, since an extension of the Ohio River and Charleston Railroad passes along the river bank.

About 1½ miles below the mouth of Caney River, where the stream is about 200 feet wide, there is a fall of 25 feet, or a little more, in a distance of a half mile, but as elsewhere throughout this portion of its course, there is no building room close to the river, though sites could be found near the summits of the hills.

TRIBUTARIES OF NOLICHUCKY RIVER.

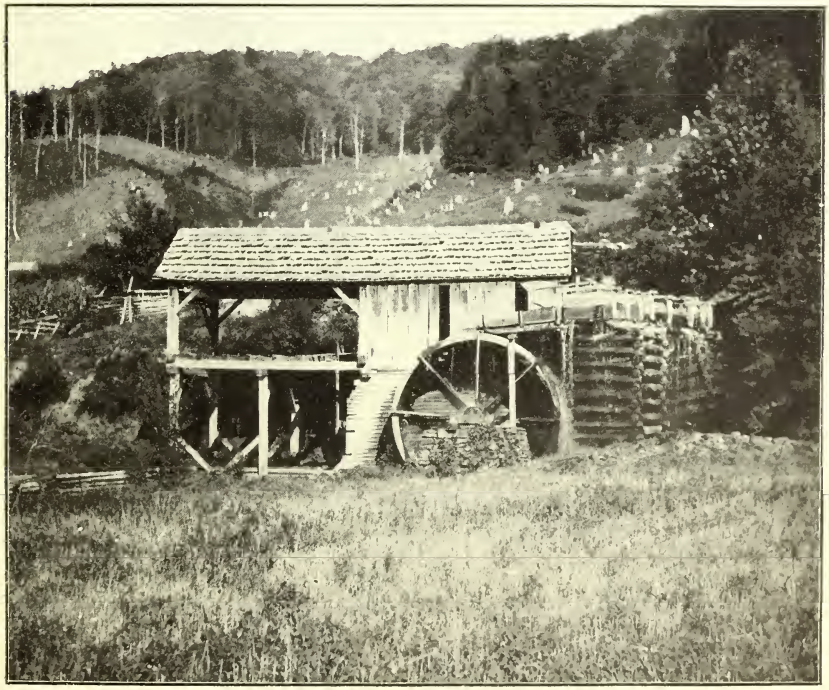
DISCHARGE MEASUREMENTS.

The drainage basins of the principal tributaries of the Nolichucky down to Embreville, Tenn., were visited and the following measurements were made, in order upstream:

Discharge measurements of tributaries of Nolichucky River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Aug. 22	Rock Creek	100 yards above mouth, Tennessee	L. V. Branch	3.69	6.37
Do	North Indian Creek.	Unicoi, Tenn	do	4.58	37.9
Do	do	Erwin, Tenn	do	3.95	51.0
Sept. 4	do	do	do	4.19	22.0
Sept. 19	do	do	E. W. Myers	4.05	29.7
Oct. 16	do	do	L. V. Branch	4.18	26.13
1901.					
June 18	do	do	E. W. Myers		174.0
1900.					
Aug. 23	Martin Creek	Near Erwin, Tenn	L. V. Branch	1.59	7.55
Sept. 4	do	do	do	1.68	6.45
Aug. 23	South Indian Creek.	do	do	5.38	52.3
Sept. 4	do	do	do	5.49	33.2
Sept. 19	do	do	E. W. Myers	5.40	53.0
Aug. 23	Hollow Poplar Creek.	Ford of Erwin-Bakersville road, North Carolina.	L. V. Branch	8.15	5.98
Oct. 16	do	do	do	8.26	2.61
Aug. 24	Toe River	Near Huntdale, N. C	do	15.89	381.0
Oct. 17	do	do	do	16.12	301.0
Aug. 27	North Toe River.	At ford of Linville-Cranberry road, North Carolina.	do	3.60	18.0
Do	do	Plumtree, N. C	do	7.55	79.0
July 2	do	Near Sprucepine, N. C	H. A. Pressey		323.0
Aug. 26	do	do	L. V. Branch	18.20	105.0
Oct. 21	do	do	do	18.37	78.0
Oct. 25	do	do	do	17.15	570.0
Aug. 24	Pigeon Roost Creek.	At mouth, North Carolina	do	7.39	14.5
Oct. 19	do	do	do	7.47	4.12
Aug. 24	Big Rock Creek	Ford of Huntdale-Bakersville road, North Carolina.	do	2.42	51.3
Oct. 19	do	do	do	2.64	24.5
Sept. 3	Jack Creek	At mouth, North Carolina	do	6.09	8.71
Oct. 19	do	do	do	6.10	6.83
Sept. 3	Pigeon Creek	do	do	5.86	1.65
Oct. 19	do	do	do	5.85	1.26
Aug. 24	Cane Creek	One-half mile above mouth, North Carolina.	do	9.20	11.78
Oct. 19	do	do	do	9.26	9.92
1901.					
Oct. 21	do	Bakersville, N. C	E. W. Myers		22.82
Oct. 22	do	do	do	0.99	21.05
1900.					
Aug. 25	Brush Creek	Lower ford of Burnsville-Sprucepine road, North Carolina.	L. V. Branch	1.39	4.37
Oct. 20	do	do	do	1.51	0.72
Aug. 25	Crabtree Creek	Ford of Burnsville-Sprucepine road, North Carolina.	do	7.97	15.2
Oct. 20	do	do	do	7.91	14.55
Aug. 25	Snow Creek	Wing, N. C	do	3.03	2.0
Aug. 26	Bear Creek	Flatrock, N. C	do	3.76	4.67
Oct. 20	do	do	do	3.70	3.73
Aug. 26	Grassy Creek	Sprucepine, N. C	do	5.21	6.09
Oct. 20	do	do	do	5.13	9.15
Aug. 26	Beaver Creek	Near Sprucepine, N. C	do	4.50	3.29
Oct. 21	do	do	do	4.29	3.08
Aug. 26	Threemile Creek	Near old post-office at Elsie, N. C	do	5.38	2.63
Oct. 21	do	do	do	5.30	3.57

A. SPLASH DAM ON LITTLE RIVER, TENNESSEE.



B. COMBINED SAWMILL AND GRISTMILL ON PRICE CREEK, YANCEY COUNTY, N. C.

Discharge measurements of tributaries of Nolichucky River—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Aug. 27	Hensons Creek	At mouth, North Carolina	L. V. Branch	6.94	4.8
Do	Plumtree Creek	Plumtree, N. C	do	2.99	8.09
Do	Roaring Creek	At mouth, North Carolina	do	7.89	15.57
Do	Squirrel Creek	One-fourth mile above mouth, North Carolina.	do	3.12	11.2
Aug. 28	Horse Creek	At mouth, North Carolina	E. Graves	5.55	9.03
Oct. 24	do	do	L. V. Branch	5.15	40.53
Aug. 27	Whiteoak Creek	do	do	2.26	3.36
Do	Kentucky Fork of North Toe River.	do	do	2.85	9.7
Aug. 31	South Toe River	One mile above mouth of Three Fork Creek, North Carolina.	do	4.34	26.0
Oct. 26	do	do	do	3.30	101.0
July 1	do	Ford of Micaville - Sprucepine road, North Carolina.	H. A. Pressey		220.8
Aug. 25	do	do	L. V. Branch	8.08	79.8
Aug. 30	do	do	do	7.98	86.23
Oct. 27	do	do	do	7.23	282.9
Aug. 30	Cane Branch	Ford of Micaville-Marion road, North Carolina.	do	3.92	2.98
Oct. 26	do	do	do	3.78	8.59
Aug. 30	Little Crabtree Creek.	Just above lower ford of Micaville-Sprucepine road, North Carolina.	do	4.28	17.54
Oct. 27	do	do	do	4.23	21.67
Aug. 30	Brown Creek	Ford of Micaville-Marion road, North Carolina.	do	3.02	4.94
Oct. 26	do	do	do	2.85	9.43
Aug. 30	Whiteoak Creek	At mouth, North Carolina	do	4.66	4.40
Oct. 26	do	do	do	4.28	19.86
Aug. 30	Locust Creek	do	do	1.98	3.83
Oct. 26	do	do	do	1.87	7.96
Aug. 31	Colbert Creek	Ford of Micaville-Marion road, North Carolina.	do	3.87	2.51
Oct. 26	do	do	do	3.50	7.24
Aug. 31	Middle Creek	do	do	3.94	3.78
Oct. 26	do	do	do	3.64	9.20
Aug. 31	Rock Creek	do	do	1.96	6.92
Oct. 26	do	do	do	1.62	28.68
Aug. 31	Three Fork Creek.	One-fourth mile above mouth, North Carolina.	do	1.49	9.49
Sept. 1	Caney River	Near Big Tom Wilson's, North Carolina.	do	1.33	17.11
Oct. 18	do	do	do	1.34	13.9
Aug. 24	do	Huntdale, N. C	do	3.69	89.9
Sept. 3	do	do	do	3.82	62.77
Oct. 17	do	do	do	3.83	58.3
Sept. 2	Big Creek	At mouth, North Carolina	do	2.83	5.67
Oct. 17	do	do	do	2.89	2.0
Sept. 2	Little Bald Mountain Creek.	do	do	4.91	2.12
Oct. 17	do	do	do	4.90	2.61
Sept. 2	Bald Mountain Creek.	One mile above mouth, North Carolina.	do	3.43	19.7
Oct. 17	do	do	do	3.55	10.6
Sept. 2	Elk Shoal Creek	At mouth, North Carolina	do	1.63	1.29
Do	Bald Creek	Near Burnsville, N. C	do	4.56	16.25
Oct. 18	do	do	do	4.56	9.97
Sept. 2	Price Creek	do	do	2.48	9.46
Oct. 18	do	do	do	2.53	8.35
Sept. 1	Bowlems Creek	do	do	5.03	3.45
Oct. 18	do	do	do	4.97	4.02
Sept. 1	Cattail Branch	do	do	2.78	2.77
Oct. 18	do	do	do	2.64	4.69
Sept. 1	Elk Fork Creek	Near Big Tom Wilson's, North Carolina.	do	1.24	4.78
Oct. 18	do	do	do	1.28	1.49

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

Descriptions of the drainage basins and water powers of the larger of these tributary streams are given on the following pages, in order upstream.

NORTH INDIAN CREEK.

Around Erwin, Tenn., and up North Indian Creek there is a very picturesque farming country. The creek drains a large area, the upper part of which is mountainous, with steep slopes, while near the Nolichucky it broadens out into a fertile valley. The low-water discharge was measured and found to be 22 second-feet. On this creek, at Unicoi, Tenn., the Unaka Milling and Lumber Company has a large wood-working plant and gristmill. Their power (about 40 horsepower) is developed by 20-inch and 24-inch turbines working under a head of 16 feet. Just above Unicoi an old ore washer formerly utilized a fall of 30 feet, but it is now out of use. On Dick Creek, a tributary of North Indian Creek, there are four falls averaging 30 to 40 feet each. In the limestone cove on North Indian Creek there are four gristmills using the water power. This cove is a widening of the valley of the creek, and in it are a number of good farms under cultivation. Much limestone is found over this entire section of country. Two miles above Erwin, on the Nolichucky, J. T. Wilder has a sawmill and wood-working plant. The dam across the stream is 17 feet high and backs the water in the river three-fourths of a mile. About 80 horsepower is developed by one turbine.

SOUTH INDIAN CREEK.

Entering the river from the south, about 2 miles above Erwin, is South Indian Creek, a stream in many respects similar to North Indian Creek, though the proportion of cleared land in its basin is somewhat less.

The creek rises on the northern slope of the Unaka Mountains, draining an area the upper part of which is made up of high, steep, and rugged mountain slopes, which as a rule are very densely forested. As the stream is descended, however, the mountains recede from it and leave broad and fertile bottoms, which are entirely cleared and under cultivation, grass, corn, and wheat being the principal crops. The cleared areas form a very small part of the whole basin, however, probably less than 10 per cent.

A great deal of timber is being cut in this area, particularly near the heads of the smaller tributaries near its mouth, and there are several small sawmills located on the creek which cut part of this product, the remainder being worked upon the spot by the small portable sawmills which are moved from place to place as the timber is cut.

At the time the stream was visited in September, 1900, its discharge was very low—about 33 second-feet. It is said to have reached a lower stage during the summer and fall of that year than ever before. The flood rise at the mouth is between 7 and 8 feet.

HOLLOW POPLAR CREEK.

This stream, which receives its drainage from the eastern slope of the Unaka Mountains, has a low-water flow of about 6 second-feet. Excepting the lower 2 miles, where there are several small farms, the creek valley is very narrow, with almost no land under cultivation. The side hills are steep and are heavily covered with timber and underbrush. The slope is greater than that of either North Indian Creek or South Indian Creek, the total fall from source to mouth, a distance of 5 miles, being about 2,000 feet. The fall is greatest near the headwaters, where it is a mountain stream jumping from ledge to ledge down the side of the mountain. There is no cleared land except near its mouth, the steep slopes being covered with the original forest growth.

NORTH TOE RIVER.

The North Toe rises on the western slope of the Blue Ridge, in the northeastern part of Mitchell County. Its course is circuitous, flowing first to the southwest, then to the west, and then to the northwest, receiving numerous tributaries, the chief of which is the South Toe, which unites with it on the line between Mitchell and Yancey counties. Practically the whole of Mitchell County is drained by the North Toe and its tributaries, the Nolichucky proper receiving the drainage from the extreme western part of the county, a small part of the northeastern section draining into Elk Creek, a tributary of the Watauga, and another small portion of the eastern section being drained by Linville River.

The region of the headwaters of the North Toe is very rough, with steep mountain slopes and narrow valleys sparsely populated. Along Whiteoak Creek and for a distance on the main stream and the Kentucky Fork above their junction the valley is wide and flat, but is heavily timbered. Part of it is in a rather swampy condition and is covered with heavy laurel thickets. Below the mouth of Whiteoak Creek the mountains close in and form a narrow and steep gorge as far down as Horse Creek. There the valley widens out a little, and from there down there is some bottom land under cultivation on each side of the river.

The tributaries of the river in this section and as far down as Sprucepine flow directly from the mountains in narrow gorges. They are for the most part short streams with great fall but with little water. The only cleared land along them is within a half mile of their mouths or on top of the mountains from which they flow, the mountain sides being too steep for successful cultivation. Throughout the region from the head of the river and its tributaries down to Sprucepine and to the mountain summits on either side probably not more than one-sixth of the land is cleared. The cleared areas are

nearly all planted in wheat and corn, although a small portion is in grass, for grazing purposes. A few miles above Sprucepine the mountains recede from the river, leaving a very wide valley, which extends down to the Cane Creek Valley on the north side of the river, and to Caney River on the south side. This valley is rather hilly throughout most of its area, and the land is cleared on the north side between Sprucepine and Bakersville. On the south side most of the cleared land is around Burnsville, although there are a number of farms near Sprucepine and along Grassy Creek.

One mile above the mouth of Pigeon Roost Creek and just above the ford there is a very good site for the construction of a dam. A water power of considerable magnitude could be developed here. Lying to the south of the main channel of the river is an island which rises about 15 feet above the water level and is never overflowed, not even during the highest floods. There is a heavy fall in the river, and by the construction of a dam from the end of the island to the north bank of the stream all of the water could be turned into the narrow channel behind the island and a fall of 15 feet or more be obtained.

Above this point there are many shoals, the river having a large fall throughout that part of its course, flowing in a deep gorge, with sides rising at angles of 30 to 40 degrees. There are several small mills on the upper part of the river, but the larger portion of the power developed in the basin is derived from the tributaries, the needs of the mills requiring the development of only a few horsepower at any place. Powers of considerable magnitude, however, can be developed on these streams, for notwithstanding the amount of water carried by each one is small the fall obtainable in a short distance is large, and absolutely safe locations for buildings can be obtained, which is not always the case on the main river.

The first mill of any size on the North Toe is just above the mouth of Bear Creek. It is a gristmill, mica-grinding mill, and wood-carving establishment. The owners have developed a 6-foot fall and claim to have about 75 horsepower. At Elsie, farther upstream, there is a combined flour mill, sawmill, and gristmill with a small dam giving a 10-foot fall.

Just below the mouth of Plumtree Creek Vance Brothers have a combined mica mill and sawmill, using a large part of the low-water flow in the river with a 36-inch Samson turbine under an 11-foot head. Mica is abundant throughout this district, and is mined extensively from Plumtree Creek down the river as far as Big Rock Creek on the north and Caney River on the south. In this district there are also several water powers developed for grinding mica.

The swift-flowing tributary streams of the North Toe, with their numerous vertical falls, furnish abundant power for small mills, and a number of the power sites have been developed, though in a small way.

On Pigeon Roost Creek, which enters Toe River 2 miles above the mouth of Caney River and has a low-water flow of about 14½ second-feet, there are two large mills, the first a small sawmill and gristmill about 100 yards above its mouth, utilizing a fall of 16 feet; the second one a sawmill and gristmill 3 miles upstream, using an overshot wheel.

There are only two rolling mills in Mitchell County—one on Big Rock Creek, belonging to Henry Master and having a capacity of 30 barrels per day; the other on Cane Creek, just below Bakersville, and having about the same capacity. At Magnetic, on Big Rock Creek, there is a large mica mill, and at the mouth of Beams Creek is located Garland's mica mill, using a 15½-inch Leffel wheel. On Cane Creek there is a sawmill just above its mouth, and at Wing, on Snow Creek, J. C. Phillips has a sawmill and gristmill using two overshot wheels of 14 and 15 feet diameter, respectively. Above this mill there are two small gristmills on Snow Creek.

On Crabtree Creek, 4 miles above the mouth, there is a fall of 100 feet, 40 feet of which is in a clear vertical leap. Six mica mills, run by one turbine under 116 feet head, are located at this place. On Bear Creek there are two small corn mills with a fall of 20 feet and 12 feet, respectively. On Beaver Creek there is a combined sawmill and corn and wheat mill run by an overshot wheel and a Leffel turbine with an 18-foot fall. Farther up the stream there is a small corn mill run by a 16-foot overshot wheel.

On Hensons Creek (marked Powdermill Creek on atlas sheet—an obvious error, for Powdermill Creek is the unnamed tributary just above it) there are three mills. The lower one is a small gristmill run by a tub wheel. Above this is Houston's sawmill, gristmill, and planing mill, run by a Leffel wheel under a 35-foot head. The upper mill, Green's sawmill, has an overshot wheel and 23 feet fall. On Plumtree Creek there is a mill, run by using the 12-foot fall on a turbine wheel, making pins for telegraph wires. One mile above, on the same creek, there is a mica mill using 91 feet fall on a turbine. Still higher up on Plumtree Creek there are four small corn mills. Powdermill Creek, Hensons Creek, Roaring Creek, and Squirrel Creek, running down the sides of the mountain, have almost unlimited falls but little water. The discharge of these streams at their lowest stages is as follows: Hensons Creek, 4.8 second-feet; Powdermill Creek, barely 1 second-foot; Roaring Creek, 16 second-feet; and Squirrel Creek, 11 second-feet.

By far the largest tributary of the North Toe is Big Rock Creek, which with its tributary Little Rock Creek rises on the southern slope of the Iron Mountains, which form the dividing line between Tennessee and North Carolina. They receive a large part of the drainage from those high and rugged mountains, the culminating peak of which is Roan High Knob, with an elevation of 6,313 feet. Cloudland, a noted summer resort on this peak, affords one of the finest

views obtainable from any of the summits of the Appalachian Mountains. Here is a very comfortable summer hotel, pure water, cool climate, and all that goes to make a pleasant and healthful summer resort. A narrow-gage railroad passes through Roan Mountain Station, 12 miles from Roan High Knob, from which point a good road has been built up the mountain side. When on Roan Mountain the Black Mountains, Hawks Bill, Table Rock (on Linville River), and the mountains of Virginia and Tennessee are in full view. One can but wonder why more is not known of these mountains and why the visitors are so few. It is, however, probably a matter of only a few years before this region will be one of the great mountain resorts of the country.

SOUTH TOE RIVER.

This river rises in the southern part of Yancey County, N. C., and flows directly north into the North Toe. It receives its drainage from the eastern slope of the Black Mountains and the western slope of Sevenmile Ridge. It follows close to the base of the latter ridge, which rises abruptly from the water's edge. On the west side of the stream the steeper slopes of the Black Mountains are about 2 miles from the river, leaving a narrow valley between. There are, however, no farms on either side of the stream, and even in the narrow valley on the west side only a few tracts (hardly one-fifth of the area) have been cleared for cultivation. Considering the drainage basin from the river to the mountain summits on both sides, probably not 1 per cent of the land has been cleared. About 2 miles above the mouth of the river the mountains on both sides recede, leaving the land from that point to the North Toe level compared with the rest of the region, although it is still a very hilly country.

Little Crabtree Creek, with a minimum discharge of 18 second-feet, is the largest tributary of the South Toe. It rises near Burnsville, in the foothills of the mountains, and joins the river a short distance northeast of Micaville. The river has seven other small tributaries, ranging in size from 2.5 to 9.5 second-feet at their lowest mid-summer flow.

There is not a mill on the South Toe, and only one or two small corn mills on its tributaries. The steep watershed and the short tributaries carry the rainfall quickly to the main stream, causing rapid fluctuations and high floods, making mill improvements difficult and expensive. This probably accounts for the few power developments in the watershed.

CANEY RIVER.

This river also rises in the southern part of Yancey County and flows northward uniting with Toe River to form the Nolichucky. It receives its drainage from the western slopes of the Black Mountains

and the eastern slopes of the Bald Mountains, and has a minimum discharge of about 63 second-feet from a drainage area of about 158 square miles. The western slopes of the Black Mountains are similar to the eastern slopes, which are drained by the South Toe, being steep and heavily wooded, the forest growth changing from the foot to near the top, where little except balsam is able to stand the low temperature. Near the foot of the mountains large areas are covered with heavy laurel thickets.

Unlike the South Toe, most of the cleared land along Caney River is in its upper and middle portions, while along its lower course the stream flows through a valley so narrow that it may be considered almost a gorge. The valley above Burnsville, however, is wider than that of the South Toe and has a larger percentage of cleared land. One mile below Burnsville the river enters a narrow gorge through which it runs for about 3 miles, but even here the higher lands are largely cleared. Farther down, the country is flat and well cleared for 6 or 7 miles; then the river enters the narrow gorgelike valley through which it flows, with many twists and turns, around the mountain knobs to its mouth. In this gorge there are very few places wide enough for clearing, but on the mountain sides the land is cleared except in the steepest parts. During the last summer (1900) the Ohio River and Charleston Railroad was extended up Nolichucky River as far as the mouth of Caney River, and since that time much lumbering has been done in this section, as already mentioned. Of the area drained by Caney River perhaps one-fourth is cleared. Fully one-half of the valley land is cleared and is largely under cultivation. Wheat and corn are the principal crops. Near the head of the valley lives Big Tom Wilson, one of the earliest settlers in this region and the man who found Professor Mitchell after his ill-fated expedition and untimely death.

The only tributaries of Caney River of any size are Bald Creek, which has a low-water flow of 16 second-feet, and Bald Mountain Creek, which has a low-water flow of 20 second-feet. There are other smaller tributaries, ranging in their low-water discharge between 1.3 and 9.5 second-feet.

Only one water power on Caney River has been developed, and this by a small gristmill located about halfway between Burnsville and the mouth of the river. A large tract of land at the headwaters, including the northwestern slope of Mount Mitchell, is owned by Colonel Murchison, of New York, who holds it as a game preserve.

FRENCH BROAD RIVER.

GENERAL FEATURES.

French Broad River rises on the eastern slope of the Tennessee Ridge, between Jackson and Transylvania counties, N. C., flows in a general northeasterly direction across Transylvania and Henderson

counties, a distance of about 30 miles, then northward across Buncombe County, a distance of more than 20 miles, then northwesterly across Madison County, a distance of 20 miles, through the Great Smoky Mountains and into eastern Tennessee, where it is joined by the Nolichucky and the Holston, and finally enters Tennessee River, its waters eventually reaching the Mississippi and the Gulf of Mexico. For convenience the drainage basin has been divided into two parts: (1) The area drained by the river in North Carolina, and (2) the area drained by it in Tennessee.

WATERSHED IN NORTH CAROLINA.

The portion of the drainage basin of French Broad River in North Carolina is comprised within the limits of Transylvania, Henderson, Buncombe, and Madison counties. The small streams from the mountains in the upper part of the watershed soon reach the wide plateau and unite into a broad and sluggish river, with practically no shoals or falls. Little clearing has been done on the upper watershed, but an extension of the Transylvania Railroad has just been completed as far as Jeptha, for the purpose of transporting lumber. The terminus of this extension is called Toxaway. The larger part of the land around the headwaters of the main stream as far as the North Fork is owned by the Toxaway Company, and they expect very soon to commence extensive lumbering operations.

Through all of this region springs are numerous, and the water is pure and cold. Above Jeptha there is very little pasture land, but the region appears to be well adapted to grazing. The mountains around the head of the North Fork are high, many of them reaching an elevation of 6,000 feet. They are traversed by trails only, the forests being still in a wild condition and the region but sparsely populated. The watershed of the North Fork as a whole is not thickly wooded, but no timber cutting has been going on for a long time. Most of the land east of this stream, including the large area of Pisgah Ridge, is owned by Mr. George W. Vanderbilt and is under the care of an expert forester. Above Jeptha the mountains close in to the banks of the stream, and consequently the branches are short and the slopes steep. Between the mouth of Tucker and Shoal creeks, on the North Fork, are some excellent shoals, but no suitable locations for large buildings, although there are shelves of rock on each bank throughout the entire distance. The fall here is about 30 feet in 200, consisting of three drops about 100 yards apart, with rapids intervening. The water power has not yet been utilized.

The drainage area of the river above Asheville is 987 square miles; the total drainage area in North Carolina 1,745 square miles. Of this total area at the time the Tenth Census was taken 1,091,000 acres were under cultivation and 8,079,000 acres, or 78 per cent of the whole, were still forest covered. In 1890, according to information

gathered for the Eleventh Census, about 30 per cent of the area was cultivated land, and as the rate of clearing has been accelerated during the last decade, on account of the large development of the lumber industries, it seems safe to conclude that at the present time about 40 per cent of the whole area is either cultivated land or land from which the timber has been removed.

Transylvania County, in which are the headwaters of the river, is a true mountain region, having on its southern boundary the Blue Ridge in its most massive and imposing form, and being the starting point of the great Pisgah and Balsam ranges, which stretch through the county toward the north. The only exceptions to the rugged topography are the broad and fertile valleys of the French Broad and its tributaries, which are cultivated and in a high state of improvement, being among the most valuable and productive farming lands in the State. These valleys are the scene of an important stock-raising industry, which is the principal source of revenue, though enormous crops of cereals and grasses are produced, some tobacco is raised, and fruits of large size and fine flavor are grown. The greater part of the county is still in the original forest growth of the usual varieties found in these mountains, which attain great size on account of the surpassing fertility of the soil. There are extensive areas of white-pine timber which will yield fairly good lumber. The merchantable trees of walnut and cherry have been largely removed, though an occasional walnut of fair size is seen, and small tracts of cherry are said to exist on the higher mountain slopes. Large tracts of poplar are also to be found, and but little oak has been cut. It is estimated that of the total area of the county only about 15 per cent is cleared land.

There has been no development whatever of the mineral wealth of Transylvania County, though gold, silver, lead, copper, nickel, asbestos, corundum, and mica are said to exist in the vast wilderness of the Balsam and the Pisgah mountains.

Henderson County is the northward or downstream continuation of the valley of the French Broad, and its topographic features are similar to those of Transylvania County, except that its areas of comparatively level and fertile land are larger and the general aspect of the country is less mountainous. A remarkable feature is the apparent great depression of the surface and the width of the stream valleys, some of which assume, as on Mud Creek, the character of a wide swamp. This depression is, however, apparent and not real, the most depressed portions being above the level of the Blue Ridge plateau. The hillside slopes are very gentle.

The soil on the uplands is not remarkably fertile, being a light-gray gravelly or sandy loam. The soil in the valleys is in large part alluvial, with much vegetable matter, and yields large crops of grains, grasses, vegetables, and fruits. Corn grows well, especially in the valleys, but the principal agricultural industry is the production of

cabbages and other vegetables for market. A great deal of fruit is also grown, and is either canned or dried.

Along the stream valleys of Henderson County pine is the predominant growth, but on the uplands oak, chestnut, hemlock, and pine are to be found, while near the summit of the mountains and in the cold and sheltered coves walnut, cherry, maple, and an occasional white pine are seen. The lumber industry, however, is of small importance, though some logs have been floated to Asheville, and small amounts of timber are cut annually for local uses. Some tan bark is also gathered.

Although the proportion of comparatively level land in this county is very great, a smaller proportion of the area is cleared than in either Madison County or Buncombe County, the cleared land amounting to about 31 per cent of the whole, according to the returns of the Eleventh Census, and only small amounts of clearing have been done since that time, so that it is improbable that the cleared land now amounts to more than 35 per cent of the entire area.

The country rock throughout Henderson County is for the most part a gneiss, but the valley of Boylston Creek is in a schistose limestone of a gray-blue color, which in places carries thin veins of quartz. The mineral wealth of the county is greater than that of either Madison County or Buncombe County. What is said to be the largest deposit of zircon in the United States occurs in the valley of Green River, and gold is found at the Boylston mine, on the southeastern slope of Forge Mountain, 13 miles west of Hendersonville.

The general surface of Buncombe County, the next county to the north, is more hilly than mountainous, with stream valleys narrow and limited in extent, which, however, offer good facilities for agricultural operations. Between Asheville and Alexander the country on the north side of the river as far as could be seen was gently rolling, with slopes of from 5 to 15 degrees, about two-thirds cleared and largely cultivated in grass. On the south side of the stream the country preserves the same general character, but the hillside slopes appear gentler, averaging between 5 and 10 degrees, about the same proportion of land being cleared. The forest growth, which for several miles back from the stream is in small segregated areas—too small to affect the run-off—is more largely pine than in the basins heretofore described. A number of tributaries rising in the gaps of the mountains enter the main stream, adding much to the beauty of the scenery. Every year great numbers of tourists visit the valley of the French Broad in search of health or pleasure. Pl. XXX is a view on Swannanoa River, one of the favorite streams of nature-loving tourists.

The upland soils in Buncombe County are stiff, even-grained loams, rarely sandy, generally deep, being derived from the disintegration *in situ* of gneiss, and are on the whole very fertile. The soils on the lowlands are rich sedimentary loams, with much vegetable matter

SWANNANOA RAPIDS ON SWANNANOA RIVER, NORTH CAROLINA.

along the smaller streams. Along the larger streams are loams similar in character to those on the smaller streams, but more sandy and less fertile. The hills erode rapidly when unprotected, but are generally quickly seeded with grass, producing a retentive turf.

The soils produce all of the cereals, grasses, and fruits, wheat yielding 10 or more bushels to the acre. Oats do well. Corn thrives, producing from 30 to 40 bushels to the acre, while clover and the grasses yield fine crops of hay. In recent years more and more attention has been paid to the raising of beef cattle for market, and this is now an important industry throughout the county. Many chickens and turkeys are also raised, these selling for good prices. Of the fruits, apples are produced in greater abundance than any other, and they are of large size and fine flavor. All vegetables grow well, the cabbages being particularly good. Tobacco is largely cultivated along the river and on the hills a few miles back from it, these localities seeming best adapted to its production. A good grade of bright tobacco is obtained.

The timber in Buncombe County includes all of the varieties found in the mountains—oak, hickory, walnut, beech, birch, chestnut, locust, pine, spruce, and others, with a dense undergrowth of dogwood, laurel, azalea, and other shrubs. There are large mills sawing lumber at Asheville and many small ones in close proximity to the timber. A considerable quantity of tan bark is also shipped from the county, the oak stocks being generally sold for fuel after being barked, but as a rule no use is made of the hemlock stocks. Walnut, curly birch, and curly ash are shipped in the log to veneering factories, but the merchantable trees of this class have been largely removed, and poplar and cucumber trees, which furnish the chief building materials of the region, are also becoming scarce. Timber that can be floated, such as pine, poplar, and chestnut, has been largely removed to supply the mills at Asheville, but little oak has been cut. According to the returns of the Eleventh Census, about 25 per cent of the area of the county was at that time cleared land. Since then, however, much clearing has been done, so that it is estimated that at the present time 40 per cent of the area is cleared; some estimates place the amount of cleared land at 50 per cent, and it is generally stated that about two-thirds of the cultivable land is cleared. Mr. George W. Vanderbilt is the largest owner of forest lands in the county. He owns many thousand acres to the south and east of Asheville, and modern scientific methods of forest management have been inaugurated in all forests owned by him.

As has previously been stated, the country rock of Buncombe County is principally a gneiss, though there are areas of granite, and across the southern edge of the county there is a narrow belt of slates and schists. The mining industry is unimportant. Talc is met with occasionally, nickel is seen in very small quantities, and a serpentine of good quality occurs in abundance between Weaverville and Leices-

ter, but the vein has never been worked. Magnetic iron ore has also been found at several places. It is said that many years ago some of the latter veins were worked; and a deposit has recently been opened at the Blackwell mine, near Blackwell Springs. Limonite is found in many places throughout the county, and brick clay is abundant. The latter is made into common and pressed brick at several yards, some fire brick is made, and a plant at Biltmore formerly manufactured drain and roofing tile and paving brick.

Mineral springs of divers kinds are abundant, those carrying sulphur being the most noted. There are also numerous nonmineral springs, which furnish large amounts of water to the streams.

The country roads furnish the chief means of transportation throughout the county, and while there has been a movement for good roads, particularly in the region near Asheville, the greater portion of the country roads are poorly graded and become almost impassable in the winter, on account of mud.

Madison County, the next county through which the French Broad flows, is also essentially a mountain country, there being very little valley land and the whole area being traversed by mountain ridges ranging in height from 2,500 feet to 4,500 feet above sea level. None of the ranges, however, rise to so great heights in this county as they attain in the adjoining counties, even the Great Smokies being below their average elevation. The soil is very fertile and produces fine crops, though from the almost entire absence of transportation facilities the agricultural products are limited to little more than enough to supply the inhabitants, a very small amount being raised for market. The hills are especially adapted to the production of a good grade of bright tobacco, large quantities of which were formerly grown and marketed in Marshall or Asheville, but recently, on account of the low prices obtained, this industry has suffered a diminution, and the "deadening," as the exhausted tobacco fields are known locally, are to be seen on many hillsides, either uncultivated or growing corn or other grain. Stock raising produces a large annual revenue, which could be considerably increased.

The mineral wealth of the county is known to be large, but it is mostly undeveloped. Magnetic iron ore, chromic iron ore, manganese, nickel in small quantities, corundum, serpentine, talc, and baryta are all found. Some corundum has been mined and shipped, much baryta has already been taken out and is still being mined by many individual miners. Recently a talc mine has been opened near Stackhouse, which is said to produce a very good quality of that mineral.

The timber found throughout Madison County is remarkably fine. Walnut trees 8 feet in diameter, poplars 10 feet in diameter, wild cherry, black birch, and buckeyes 3 or 4 feet in diameter are met with occasionally, while the common timber trees, such as oak, chestnut, and pine, are plentiful and of large size. Much timber has already been taken out and much is still being logged wherever the crude

FRENCH BROAD RIVER AT PAINT ROCK, N. C.

methods of lumbering prevalent can reach it. There are large mills at Stackhouse and at Putnam, and small portable mills are located wherever the timber can profitably be attacked, the lumber being wagoned to the railroad for shipment.

The geologic formations of the county are similar to those of Cocke County, Tenn. Close to the State line there is a belt of sandstone, which is succeeded by slates and schists. About a mile below Hot Springs the latter give place to limestone and dolomite, which above the springs are succeeded by sandstones, slates, and schists, and these in turn by the gneisses and granite which are the predominant rocks of the county.

The Hot Springs mentioned as being located in the limestone belt constitute one of the most interesting features of the region. They are 6 or 7 miles above the Tennessee line, directly on the banks of the river, some springs indeed bubbling up in the bed of the stream. As the name indicates, the water is warm, although of varying degrees of temperature, and possesses many valuable medicinal properties, said to be particularly efficacious in rheumatic cases. There is a large hotel at the springs, and many people come to take the hot baths, for which the waters are chiefly used.

Throughout its course in Madison County the river flows in a deep gorge which it has carved out in the gneisses and slates, now twining among the hills and now cutting through them, leaving at the latter places almost perpendicular walls of bare rock several hundred feet high or slopes of from 50 to 60 degrees covered with a sparse growth of gnarled and stunted trees clinging to the interstices of the rock.

Pl. XXXI is a view of the river at Paint Rock, near the North Carolina–Tennessee boundary, and shows both the forested slopes and the perpendicular rock walls in this portion of its course. As the river is ascended the sides of the gorge become gradually lower and less steep, and the country beyond the crests of the river bluffs loses somewhat its mountainous character, becoming instead a region made up of rounded hills and swells, with broader and more nearly level valleys between, a much larger proportion of the land being cleared, the cleared areas increasing from practically none on the extreme northern, western, and southwestern borders to probably 50 per cent of the area above the mouths of Walnut and Pawpaw creeks.

Throughout this area none of the closed basins which have been so notable a feature in some other areas were noted, but instead there seems to be a greater number of small stream channels, most of them carrying some water, which was not the case over a large part of the area drained by the South Fork of the Holston.

WATERSHED IN TENNESSEE.

The part of the drainage basin of the French Broad which is situated to the east of the town of Newport, Tenn., the western limit of the investigation, is comprised entirely within the limits of Cocke

County. The area immediately about Newport and for 5 or 6 miles to the east while hilly is not mountainous, and in many respects bears a close resemblance to the country seen along the South and Middle forks of Holston River, consisting, as it does, of rather low hills and broad ridges of gentle slopes largely cleared and grass covered. In parts of this area, particularly in the part seen from the road leading from Parrottsville to Newport, numerous small closed drainage basins or sinks were observed, many of them of large size and having pools of water in their bottoms. Occasionally, over an area of a square mile or more, these sinks occur in such numbers as to absorb the entire drainage, permitting, so far as could be observed, no water to find its way into the stream channels. This will tend to produce complications when the run-off from two similarly situated areas is compared if either area contains basins. None of the basins were noted above the North Carolina line. There are numerous springs of chalybeate and sulphur water in Cocke County, and large numbers of springs whose waters possess no medicinal properties.

It is along this part of the course of the stream that the far-famed scenery of the French Broad occurs, but with all its beauty the scenery barely equals that seen when the summit of the river bluffs has been reached, where vistas of mountain and meadow, woodland and stream are spread out before the eye, scenery of which the rugged beauty of that along the river has given no promise.

If the whole area of Cocke County be considered, about 40 per cent of the land is cleared and cultivated, according to the best information obtainable; but this includes a part of the vast Unaka mountain chain, with its outlying spurs and ridges, where the proportion of cleared land is exceedingly small, so that it is estimated that from 65 to 70 per cent of the area to the west of the mountains is cleared and under cultivation or in grass, which is one of the principal products.

The mountains rise very abruptly and steeply from the more level area, and the proportion of cultivable land on them is small, being confined to the stream valleys and to a few of the lower and gentler slopes. In some of the coves and gorges the soil is productive, but these areas are too small to be of value for grain growing. They are, however, adapted to the production of grass and fruit, although very little has been done in that direction. The principal valley is of course that of the main stream, which has an average width of about 1 mile and is exceedingly fertile, the soil, which is alluvial, being deep and producing, with good cultivation, from 50 to 100 bushels of corn to the acre, this being the principal crop. Oats thrive very well, wheat not so well. Of late years more of the land has been sown to grass, and the stock-raising industry now affords a considerable revenue to the people of the county. The price of land ranges from $1 and $2 to more than $50 an acre.

There is some very fine timber in Cocke County, mainly oaks of

various kinds, chestnut, maple, hickory, walnut, white and yellow pine, spruce, and other varieties. Formerly a great many shingles were made, mostly from white pine. A limited amount of lumber is sawed annually by the small country mills for local uses, and a much larger amount of timber is annually destroyed for the purpose of stripping tan bark or for railroad ties; but taken as a whole the timber industry is of little importance, and the same is true of manufactures in general. There is a small cotton mill at Newport, also one or two small sawmills and a flouring mill, and there are small sawmills and gristmills at various places in the county, but they are of little importance.

The mineral wealth in this section is very great, but so far as could be learned nothing has been done toward developing it. Iron is said to occur in paying quantity, also lead and baryta. Newport is just at the junction of the shales and the limestone, which there form a narrow valley, and for 5 or 6 miles up the river limestone and dolomite occur, the prevailing color being blue, though layers of gray rock are also found. The limestone and dolomite are succeeded by red shales, and these, for a fourth of a mile or more upstream, by white or grayish sandstones. Passing these sandstones, shales or slates are again met with, bands of conglomerate occurring at intervals, also a few layers of dolomite. The sandstone then makes its appearance again and continues several miles up the river, or to and beyond Paint Rock.

RAINFALL.

The total annual rainfall at Asheville is 42.6 inches, distributed as follows: Spring, 11.7 inches; summer, 13.8 inches; autumn, 7.7 inches; and winter, 9.4 inches. Asheville, however, is in a region of rather low precipitation compared with the rest of the mountain country, although the records of the station at Waynesville show that the annual precipitation between Asheville and Paint Rock is very near the amount stated. Records of stations above Asheville show that the annual rainfall increases very rapidly as the stream is ascended, and near the headwaters, but across the divide, are stations having a mean annual precipitation of between 72 and 73 inches, with an occasional record of more than 105 inches.

The distribution of the rainfall is favorable to a large annual run-off in the stream, since at the time when plant life and evaporation make the heaviest demands upon the precipitation the rainfall is greatest, and it is least in autumn and winter, when these demands are at a minimum. However, since the autumn precipitation is the least and plant life and evaporation are still rather active, the stream is then subject to periods of low flow, although the run-off per square mile is large when compared with streams draining areas out of the mountains, and remains so during even the periods of severe drought.

TRANSPORTATION.

Throughout the greater part of the basin of the French Broad the transportation facilities are poor, being mainly confined to the ordinary country roads, which as a rule are steep and rough, poorly graded and ill kept. The Knoxville branch of the Southern Railway follows the course of the stream very closely below Asheville, and the Spartanburg branch of the same system runs approximately parallel to it for a long distance in the upper part of its course, while the Murphy branch furnishes railroad facilities for the inhabitants of the valley of Hominy Creek. The Hendersonville and Brevard Railroad has recently been constructed from Hendersonville to Jeptha, in Transylvania County, furnishing an outlet for the products of the upper part of the basin. But owing to the character of the country the transportation facilities are less effective than they otherwise would be, and there seems no present prospect that the conditions will be bettered, though one or more additional lines of railroad have been projected to traverse the basin. On the whole, however, the transportation facilities of the area are better than those of any other section of western North Carolina, and in consequence it is better known to the outside world and is more prosperous than the areas to the northeast and the southwest.

DISCHARGE MEASUREMENTS.

During the investigation a gaging station was established on the French Broad at Oldtown, Tenn., where measurements were made from time to time, also at other places along its course, as shown in the following table. The Survey has maintained a gaging station at Asheville since September, 1895, the results of which have been published in the annual reports.

Discharge measurements of French Broad River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-feet.*
Sept. 4	Oldtown, Tenn	E. W. Myers and L. V. Branch.	1.00	867.0
Nov. 2	do	do	1.26	1,653.0
Dec. 15	do	do	1.30	1,976.0
Dec. 26	do	do		2,901.0
Sept. 7	One-half mile above Hot Springs, N. C	L. V. Branch	19.35	938.0
Sept. 12	Alexander, N. C	E. W. Myers	17.15	840.0
Oct. 29	do	L. V. Branch	16.27	2,068.0
Sept. 18	Fanning Bridge, North Carolina	N. C. Curtis	16.22	1,161.0
Oct. 17	do	do	16.95	614.0
Sept. 17	Penrose, N. C	do	19.80	1,160.0
Sept. 13	Near Carson Creek, N. C	do	13.80	266.5
Oct. 15	do	do	13.90	206.5
Sept. 14	Eastatoe Bridge, North Carolina	do	12.40	113.0
Oct. 15	do	do	11.21	102.4

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table at Oldtown. In making all of the other measurements, however, in each case a bench mark was established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In these cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

MOUNTAIN ISLAND SHOAL, FRENCH BROAD RIVER NORTH CAROLINA.

WATER POWERS.

In describing the fall and power of the French Broad we will start near Newport, Tenn., and follow upstream to its source. At the starting point, about 2 miles north of Newport, the river is a comparatively placid stream, flowing between willow-bordered banks and through broad and fertile grass-covered bottom lands, and this character is preserved for 5 or 6 miles, when there is an abrupt descent of about 4 feet over a rock ledge extending straight across the stream. Near these falls the bottom lands almost entirely disappear and the mountains begin to close in on the river, the hillside slopes, which are sparsely forested, varying from 30 to 50 degrees. Farther upstream an occasional broad bottom is to be seen, but the mountains continue to rise higher and higher as the stream is ascended, the river entering a gorge which reaches a very highly developed stage near Paint Rock. (See Pl. XXXI.) Throughout this distance, however, there is little concentration of fall in the stream, the fall averaging about 10 feet to the mile, following the course of the river, which is very tortuous in this section.

The stream preserves the same general character as far as Hot Springs, the average fall per mile between Paint Rock and Hot Springs being about the same as in the section between Paint Rock and Newport. Above Hot Springs, however, the character of the river changes abruptly, and from a smooth though rapid stream it becomes a tumultuous mountain torrent, dashing along among many huge bowlders and over the rock ledges which obstruct its course and project above the surface in jagged ridges, twining and curving around the hills between lofty and steep walls of rock, which are thinly clad with stunted trees. The river contains many islands and is in places very wide.

In the 7.7 miles between Hot Springs and the mouth of Brush Creek the total fall is 201 feet, giving an average fall of 26.1 feet per mile. There are several places in this distance where the fall is noticeably concentrated. The first of these is about one-fourth of a mile above Hot Springs and is known as the Mountain Island Shoal. At this shoal, shown in Pl. XXXII, a high and rocky island about 200 yards long divides the stream into two parts. The most noticeable concentration of fall is at the ends of the island, there being at the lower end an almost vertical plunge of between 4 and 5 feet, and at the upper end two plunges of about 3 feet each. There is also a fall of about 4 feet in the distance between these plunges, making a total fall of about 15 feet at this place. Below the island the river contracts suddenly to a width of about 100 feet and the water is very deep and sluggish. The railroad is on the north bank, crossing the stream a short distance below the island, and as the track is only a few feet above the level of high water, it offers an obstacle to the

development of the power. A development could be made, however, but at considerable expense, by constructing a wing dam from the upper end of the island diagonally toward the north bank, gradually decreasing the height of the dam upstream. This would throw as much of the water as might be desired to the south side of the island and away from the railroad, and then by building a dam across the south channel near the lower end of the island the flow of the stream could be controlled. Space for a power house on the island could be cleared by a small amount of blasting, and the power be transmitted to Hot Springs, where there is a large area of level land. This is by far the largest and most noticeable fall on the stream, and probably would afford a cheaper and easier development than any other.

As at this fall, so at all others between Paint Rock and Asheville, the proximity of the railroad to the stream renders it impossible to build high dams, though otherwise the conditions for easy and cheap construction are very favorable, for everywhere stone can be obtained in great quantities at comparatively small cost for blasting and transportation to the site of the work.

Although the average fall per mile in the stream channel between the head of the Mountain Island Shoal and the mouth of Brush Creek is very great, there are several places where it is still more concentrated, the first of these being just above the mouth of Laurel Creek, where the fall is estimated to be about 15 feet in a little more than one-fourth of a mile, and about 2 miles below Barnard Station, where there is another large fall within a short distance. Just below and a little above the mouth of Brush Creek there is still another large fall, the banks being very high, steep, and rocky, the stream comparatively narrow, and all of the conditions for the construction of a high dam very favorable, excepting the presence of the railroad. At almost any desired place within this distance—from the Mountain Island Shoal to Brush Creek—falls of from 15 to 20 feet can be obtained.

From the mouth of Brush Creek to Asheville, a distance of 29.3 miles, the stream is still very rapid, but the average fall per mile is much less than in the section just described, being about 15.4 feet, in general well distributed. Sites where falls of 10 feet or more can be obtained are numerous, though none of them were noted particularly.

The first power developed on this stream is at Marshall, Madison County, where, on the south bank of the river, the Marshall Milling Company has erected a flour mill with a capacity of 75 barrels per day, utilizing only a small part of the flow, which is turned aside by means of a wing dam about 200 yards long extending diagonally upstream about half the width of the river, from the upper end of which a very low dam has been built to the north bank of the stream, both dams being made of logs and giving a fall of 13 feet at the wheel.

There are several other localities between Marshall and Asheville where small powers could be developed in the same way, but no attempts have been made to do this. There is a project to develop a small fall in the stream just below Asheville, to obtain power to operate street cars and electric lights, and a low dam has been built, but no other work has been done.

Above Asheville the character of the stream again changes and it becomes a placid river with a current which though rapid when compared with the streams of the Coastal Plain is very sluggish when compared with its mountain neighbors or with its own current a few miles below. The bed of the stream is overlain with a stratum of coarse sand and gravel, and in general is rather smooth, though the current is interrupted at intervals by ledges and bowlders, and the fall is very much more gradual and evenly distributed than is usual with mountain streams. The distance from Asheville to Brevard, by river, is 48.35 miles, and the total fall is 130.9 feet, making the average fall per mile only 2.7 feet. Indeed, so small is the fall that at one time the United States engineers did a great deal of work on this portion of the stream to render it navigable. Formerly a small steamboat plied the river, but it did not pay expenses, and of late no attempt has been made to navigate the stream.

There are two principal obstructions to navigation, the first of these 8½ miles above Asheville, and known as the Sandy Bottom Shoal. This is the largest shoal on this part of the river, the total fall being 22.6 feet in a distance of 18,000 feet. Three and one-half miles above this is the Long Shoal, where the fall is 18.3 feet in 12,920 feet. Above this and as far as Eastatoe Ford, about 1 mile above Jeptha, the stream flows placidly along through a broad and level valley and offers no possibility of power development. Above the ford, however, the fall rapidly increases, but the stream divides into the North and West forks, both of which are too small for consideration as power streams.

TRIBUTARIES OF FRENCH BROAD RIVER.

DISCHARGE MEASUREMENTS.

During the investigation the drainage basins of the important tributaries in North Carolina were visited and the following measurements made:

Discharge measurements of tributaries of French Broad River in North Carolina.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Sept. 14	North Fork of French Broad River.	Two hundred yards above mouth of West Fork.	N. C. Curtis		100.6
Oct. 15	do	do	do	13.2	51.8
Sept. 16	do	Bridge on Brevard-Webster road.	do	14.98	107.48
Do	do	Ford on road between Tucker and Shoal creeks.	do	7.3	75.0

Discharge measurements of tributaries of French Broad River in North Carolina—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
Sept. 14	West Fork of French Broad River.	Near mouth	N. C. Curtis	2.20	149.0
Oct. 15	do	do	do		62.0
Sept. 14	Middle Fork of French Broad River.	Bridge 20 yards above ford	do	5.35	77.0
Do	South Fork of French Broad River.	Footbridge at ford of main road.	do	10.3	71.0
Oct. 15	East Fork of French Broad River.	Near mouth	do	10.2	46.0
Sept. 16	Tucker Creek	Two hundred yards above mouth.	do	4.61	28.0
Sept. 13	Cathey Creek	Ford of Brevard-Jeptha road	do	6.7	30.2
Sept. 17	King Creek	Brevard road	do	4.71	15.46
Do	Davidson River	Near mouth	do	16.45	151.77
Oct. 16	do	do	do	16.75	70.20
Sept. 17	Little River	Three-fourths mile above mouth.	do	13.66	182.8
Oct. 16	do	do	do	14.35	69.2
Sept. 17	Boylston Creek	Near mouth	do	5.35	28.65
Do	Mills River	Bridge on Old Haywood road	do	13.11	211.64
Oct. 17	do	do	do	13.4	94.0
Sept. 18	Mud Creek	Near mouth	do	5.11	108.0
Do	Caney Creek	Bridge on Westfall's place	do	10.1	60.0
Do	Avery Creek	Bridge on road from Mills River to Asheville.	do	6.56	11.31
Sept. 19	Hominy Creek	Asheville	do	15.1	80.0
Oct 17	do	do	do	15.4	24.0
Sept. 19	Swannanoa River	Biltmore	do	2.91	76.33
Sept. 20	North Fork of Swannanoa River.	Three miles above Swannanoa.	do	16.07	21.45
Do	Flat Creek	Two miles below Black Mountain Station.	do	4.05	22.83
Sept. 12	Beaverdam Creek	Fifty yards above mouth	E. W. Myers	5.09	1.46
Oct. 30	do	do	L. V. Branch	5.08	4.10
Sept. 16	Lees Creek	Olivette	E. W. Myers	11.15	3.95
Oct. 30	do	do	L. V. Branch	10.95	2.29
Sept. 12	Newfound Creek	At mouth	E. W. Myers	17.75	9.41
Sept. 16	do	Three-fourths mile above mouth.	do	10.19	34.16
Oct. 30	do	do	L. V. Branch	10.44	20.23
Sept. 12	Reems Creek	At mouth	E. W. Myers	12.1	4.89
Oct. 30	do	do	L. V. Branch		9.0
Sept. 11	Flat Creek	do	E. W. Myers	18.05	5.33
Oct. 29	do	do	L. V. Branch	17.43	5.0
Sept. 12	Sandymush Creek	Bailey	E. W. Myers	9.73	21.72
Sept. 17	do	do	do	9.43	55.23
Oct. 30	do	do	L. V. Branch	9.53	45.0
Sept. 16	Turkey Creek	Blackwell Springs	E. W. Myers	7.97	35.24
Oct. 30	do	do	L. V. Branch	8.32	16.24
Sept. 17	Big Ivy River	One-eighth mile below mouth of Bull Creek.	E. W. Myers	2.55	47.59
Oct. 29	do	do	L. V. Branch	2.72	41.72
Sept. 8	Little Pine Creek	One hundred yards above mouth.	do	5.84	3.33
Oct. 31	do	do	do	5.76	6.0
Sept. 8	Pawpaw Creek	One mile above mouth	do	4.6	0.35
Sept. 10	Walnut Creek	At mouth	do	23.24	1.36
Oct. 31	do	do	do	2.35	2.24
Sept. 8	Big Pine Creek	One hundred yards above mouth.	do	6.07	4.85
Oct. 31	do	do	do	6.01	4.45
Sept. 8	Big Laurel Creek	Two hundred yards above mouth.	do	16.13	49.0
Sept. 18	do	do	E. W. Myers	15.77	55.0
Sept. 7	Spring Creek	Near Hot Springs	L. V. Branch	2.00	15.0
Nov. 1	do	do	do	2.07	16.0
Sept. 7	Shutin Creek	do	do	2.61	0.45

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

The principal drainage basins are briefly described on the following pages, in order upstream.

LONG CREEK.

The first tributary of any size entering the French Broad above Newport, Tenn., is Long Creek, which flows in from the north, draining a small area. At the mouth the valley of the stream is very narrow, the mountains rising high and steep on either side, in walls of almost bare rock; but farther up the valley widens greatly, and it is estimated that above the forks about half of the basin is cleared land, being made up for the most part of rather low hills, with gentle side slopes timbered in pine and oak. Corn and wheat are the principal crops; about one-third of the cleared land is in grass.

At the time the stream was visited it was extremely low, its flow being too small to gage, but it was carrying a quantity of water estimated to be between one-fourth and one-third of a second-foot. The stream is said to rise very rapidly after rains, reaching an extreme height of about 4 feet above low water. The floods are of short duration.

BIG CREEK.

Big Creek, the next tributary, enters the river from the south, near Del Rio, draining an extensive area in the high and rugged Stone and Smoky mountains, almost the entire basin being forest covered and very steep and rough, with a great deal of rock exposed on the hillsides. The cleared land is confined entirely to the narrow strips bordering the stream, but it is small in amount, being probably less than 5 per cent of the area of the basin, which may thus be considered entirely forested.

When this stream was visited it was very low, carrying an estimated discharge of possibly 2 second-feet. It rises rapidly after rains, in consequence of the great steepness of the hillside slopes over its basin, and attains a maximum height of from 5 to 6 feet above low water.

LAUREL BRANCH, MOONEYHAM BRANCH, AND ROCK CREEK.

These are very small streams which are practically dry during severe droughts.

WOLF CREEK.

Wolf Creek is the next tributary. It is a small stream entering from the south, draining a long and narrow area which with the exception of one or two small patches of an acre or two near its mouth may be considered entirely wooded. The basin is rough and mountainous, with very steep slopes. The forest growth consists for the most part of pine, with a dense undergrowth and with some oak and chestnut. Extensive lumbering operations have been carried on on

the mountain slopes over the basin, and much of the available timber has been cut, but the ground is densely shaded by the undergrowth and the nontimber trees.

This stream was not gaged, the quantity of water which was flowing, estimated to be about 0.5 second-foot, being too small to admit of measurement. It was stated by residents that the stream was then at its lowest stage. The maximum flood rise is between 4 and 5 feet.

SHUTIN CREEK.

The basin of this stream is similar to that of Wolf Creek, except that very little timber has been cut.

SPRING CREEK.

Spring Creek, entering the river from the south, at Hot Springs, is the largest tributary yet described. It rises in the extreme southern corner of Madison County, near Sandymush Bald, on the northeastern slope of the Newfound Mountains, and flows in a general northerly direction for a distance of about 20 miles, draining an area of 66 square miles. Its basin is in the midst of the high mountains, is steep, rough, and rugged, and is almost entirely forest covered, the cleared land being confined to the narrow stream valleys which constitute a very small proportion of the whole area, probably less than 10 per cent. The stream attained its minimum stage during the autumn of 1900, when it was measured and found to be carrying 0.45 second-foot. It has a maximum rise of about 6 feet during floods, which are said to be violent, but of short duration.

BIG LAUREL CREEK.

This stream, the next tributary of the French Broad, rises in two forks, one in the Bald Mountains, in the extreme northeastern part of Madison County, and the other in the Unaka Mountains, in the extreme northern part of the county. It drains an area of 141 square miles. Its basin is very rough and rugged, with a large proportion of steep, forested slopes, ranging from 15 to 50 degrees and showing a great deal of exposed rock, which is of a slaty character. For a considerable distance above its mouth the stream is in a deep gorge and could not be followed, but it was ascertained that the country was extremely rugged and contained no cleared land. The hills there lack the symmetry of those seen farther upstream, having steeper slopes and being broken into irregular shapes by the small valleys and gullies which extend up their sides.

The proportion of cleared land in the basin is small, not more than 25 per cent of the area being under cultivation. The cultivated areas are for the most part confined to the stream valleys and the lower uplands. Within the last ten years much land has been partially

cleared by cutting away the undergrowth and deadening the larger trees, the deadened areas being largely cultivated in tobacco or corn. The soil is in part red, clayey, and very impervious to water, and in part loamy, and is not very fertile.

Extensive lumbering operations are now in progress over the basin, many small portable mills being located in close proximity to the timber, the lumber being hauled to the railroad at either Putnam or Stackhouse. Poplar seems to be the timber most sought, though oak and pine are also cut. Much chestnut remains, and trees of many other varieties are found.

At its mouth the flood rise of the creek is from 7 to 8 feet. It never falls very low, the lowest stage known having been reached in the autumn of 1900, when the discharge was about 49 second-feet. While the stream is capable of furnishing power in large amounts, it is utilized by only two or three small gristmills, grinding grain for local uses.

Some baryta has been found in the basin, but so far as could be learned the principal deposits of this mineral are along the main river, on the hills between Stackhouse and Marshall. Talc is also found in this region, and some has been recently taken out which is said to be of excellent quality.

Shelton Laurel Creek.—This stream is the principal tributary of Big Laurel Creek. Its drainage basin is very similar to that of the main stream, although as the creek is ascended the topography flattens out to some extent. The stretch of the river between White Rock and Alleghany is much more level and more extensively cultivated than any seen lower down the stream. The only extensive lumbering operations carried on in the basin are in this locality, being mainly directed against the timber which can be reached from the small tributary streams, although the operations are more or less general.

The soil seems similar to that along Big Laurel Creek, but it contains a very large proportion of rock fragments ranging in size from a pea to several inches in diameter, and more quartz is seen, forming now an important part of the country rock.

The slope of the channels of this creek and its branches is very great, the storm waters reaching the streams almost immediately, the main creek rising very rapidly and falling as quickly.

BIG PINE CREEK.

The next tributary gaged was Big Pine Creek, which enters the French Broad from the south, opposite Barnard, draining a considerable area which is largely forest covered, the cleared and cultivated land being confined for the most part to the stream valley and the lower hills. The hillside slopes over the basin are almost uniformly steep and rocky, and the greater part of the area is mountainous.

WALNUT, LITTLE PINE, AND HAYES CREEKS.

Walnut Creek, entering from the north, about 3 miles above Barnard, is a stream of about the same size and general character as Big Pine Creek, except that the proportion of cleared and cultivated land in its drainage basin is considerably greater, the valley of the stream being wider and the slopes less steep and rugged, the topography consisting for the most part of rather low and rounded hills, largely grass covered, although the upper part of the basin is steep and mountainous. The cleared land amounts to probably one-third of the whole area, possibly more. The stream reached a very low stage in the autumn of 1900, lower than ever before known, it is stated. The discharge measured on September 10 was 1.36 second-feet. The maximum rise in flood is about 4 feet.

Little Pine Creek and Hayes Run are entirely similar streams, though much smaller.

IVY RIVER.

Ivy River, the next tributary, enters the French Broad from the east, and is the principal tributary in North Carolina. It rises on the western slopes of the Great Craggy Mountains, near Yeates Knob, the headwaters being at an elevation of about 5,000 feet, and flows in a general westerly direction, joining the French Broad about 2½ miles above Marshall, draining an area of 176 square miles.

For about 3 miles above its mouth the valley of the river is very narrow and the banks of the stream are steep, showing much exposed rock, but they are forested with a growth of considerable density. Above this 3-mile stretch, although the gorge formation still persists for a considerable distance, the hills do not rise to so great heights, and the country beyond the summit of the bluffs is composed of a succession of hills and ridges of moderate height, very sharp topped, and inclosing narrow V-shaped valleys, the hillside slopes ranging from 10 to 30 degrees. A large part of the area—perhaps 75 per cent—is cleared. It is probable that nearly 50 per cent of the whole area drained by Ivy River is either under cultivation or is grass. Throughout this part of its course, or to beyond Grantville, the stream channel is very tortuous.

As the stream is ascended the topography becomes less strongly marked and the country better fitted for agriculture and stock raising, until a short distance below Barnardsville the mountains begin again to encroach on the river and the cultivated lands are confined to the immediate valley of the stream. There is considerable timber yet standing in the high mountains about the headwaters, much of it being inaccessible.

Corundum has been found near Democrat, nickel stainings have been observed in the rocks at many localities, and a vein of serpentine of good quality crosses part of the basin.

The stream has a large fall throughout its length, the average fall per mile between its mouth and Barnardsville, at the junction of the forks, being about 43 feet. It could be made to furnish power in large amounts, but as yet very little has been done in that direction. About 1 mile above its mouth there is a fall of 6 feet in 200 feet, over ledges of solid rock, the width of the stream being between 60 and 70 feet.

The most important power site on the stream is about 2 miles above its mouth. Here Mr. W. B. Ellis, of Asheville, and others, have planned a large power development, which is about half completed. The plans include an arched masonry dam 95 feet in height, 360 feet long on top, 60 feet wide at base, and 12 feet thick to the 83-foot level. The race is to be 860 feet long from the dam to the power house, built partly in embankment and partly in open rock cut, with 100 feet of tunnel and 250 feet of steel flume, which will carry the water to a pair of 22-inch turbines. It is stated that the flow of the stream will be sufficient, with proper storage, to develop 2,000 horsepower under a working head of 110 feet, the natural flow of the stream yielding 1,000 horsepower under that head. The power is to be transmitted electrically to Asheville, Marshall, and other places at a potential of 10,000 or 11,000 volts. During the autumn of 1900, when the plant was last visited, all work had been suspended, due largely, it was rumored, to lack of water.

On the basis of 1,000 horsepower developed continuously, the flow of the stream at this place is calculated as follows: It is safe to assume that the losses of energy in the wheels, dynamos, and in transmission will amount to at least 20 per cent of the total energy due to the water, and as it is the intention to deliver 1,000 horsepower at the end of the transmission line, this will require of the stream a flow capable of developing 1,250 gross horsepower with a head of 110 feet, or 11.36 gross horsepower per foot of fall. One second-foot of water falling 1 foot will yield 0.1135 gross horsepower, so that in order to produce 11.36 gross horsepower per foot fall a flow of practically 100 cubic feet per second will be necessary, and during times of drought the stream does not carry that amount of water. When these notes were made, in October, 1899, although the discharge could not be gaged, it was estimated to be not much more than 50 second-feet. When the locality was visited in the fall of 1900, at a time when the stream was said to be very low, the discharge was gaged a short distance above the head of the backwater from the dam and a flow of 41.72 second-feet was found.

Just above the mouth of Little Ivy River there is a gristmill with an 8-foot dam, giving a fall of 10 feet, and at Democrat there is a similar mill.

SANDYMUSH CREEK.

The next tributary is Sandymush Creek, which joins the French Broad about 4 miles above the mouth of Ivy River. This creek rises on the northern slopes of the Newfound Mountains, in a number of small creeks which have a general northerly or northeasterly course. Including Turkey Creek, which joins it near its mouth, it has a drainage area of 86 square miles. Near its mouth and for a considerable distance upstream the creek lies in a deep and narrow gorge, but farther up the valley widens very much and the topography becomes less strongly marked over a large part of the area. The high hills which inclose the valley are rough and steep, most of them ranging from 15 to 30 degrees, but many of them being much steeper. The proportion of cleared land is smaller than in the basin of Turkey Creek, being less than half of the whole area. Above the junction of Little Sandymush Creek the area is entirely mountainous and forested, with the exception of small, narrow areas immediately along the stream. Pine trees seem more numerous than heretofore noted, the character of the hard-wood growth remaining the same, also the agricultural products. The soil is a fertile loam, the country rock a much laminated and contorted gneiss.

The stream is said to have reached its minimum stage of flow during the fall of 1900 (see measurements in table on page 128). During floods it is subject to violent rises of from 6 to 7 feet.

Turkey Creek.—The valley of this tributary of Sandymush Creek is very different in character from that of the main stream. In proportion to its size its valley is broader than that of any stream yet described. The proportion of cleared land seems to be about 75 per cent over the lower part of the basin, and is probably 66 per cent of the whole area. The topography is a succession of hills and ridges divided by broad valleys, and the hillside slopes are comparatively gentle. The soil is deep and fertile. The country rock seems without exception a gneiss. At the time the stream was visited all of the land except that in corn was covered with grass, and this is true of all this section of country during the fall and summer months. A large part of the area is planted in wheat, and when that is harvested grass quickly covers the land, remaining until seeding time comes again.

The creek falls very low at times, reaching, it is said, its lowest stage in the fall of 1900, and though subject to floods of 6½ to 7 feet, these are rare and generally of short duration.

FLAT CREEK.

The next tributary is Flat Creek, which enters the French Broad from the east, about 1 mile below Alexander. It is a small stream rising on the western slope of the Flat Creek Mountains and draining

a broad and flat valley of considerable extent. The topography is in broad and low flattened hills and ridges, the hillside slopes being very gentle. Seemingly about two-thirds of the area is cleared land, about one-half of it in grass and the other half chiefly in wheat, corn, and tobacco. The soil appears deep and fertile. No exposed rocks were seen, though the basin is underlain by gneiss or granite. The stream is subject to periods of very low flow, and during floods it rises from 5 to 6 feet at the mouth.

REEMS, NEWFOUND, AND BEAVERDAM CREEKS.

Reems Creek, the next tributary, enters the river from the east a short distance above Alexander, and seems in every respect similar to Flat Creek, just described. It was gaged at its mouth, with the results given in the table on page 128. The maximum flood rise is from 5 to 6 feet.

Newfound Creek, entering the French Broad from the southwest, rises close to the headwaters of Turkey Creek, near Turkey Creek Pinnacle, and in soil, topography, and general characteristics is a stream similar to Turkey Creek.

Beaverdam Creek, entering the French Broad from the east a short distance below Owenby, drains a long, narrow, and rather flat valley containing a large proportion of cleared land, but it is a small and unimportant stream.

SALUDA RIVER.

About 10 miles above Greenville, S. C., Saluda River is formed by the confluence of the North Saluda and the Middle Saluda. The South Saluda, a stream nearly or quite as large as the two other streams combined, enters the Middle Saluda a few miles above the junction of the latter stream with the North Saluda. The watershed of these three branches is defined by the North Carolina–South Carolina boundary line, extending from the Greenville-Pickens county line in South Carolina to the western slope of Rocky Spur, 5 miles southeast of Saluda, N. C., the total length being about 36 miles and the drainage area estimated at about 380 square miles. The watershed includes the southern slopes of the Saluda Mountains and a portion of the Blue Ridge. Below the junction of the three forks the main stream flows in a general southeasterly direction through the State of South Carolina, joining Broad River near Columbia, to form the Congaree.

The steep slopes at the headwaters of the river are densely forested, but the valleys of even the smaller tributary streams have been cleared. Oak and hemlock predominate, but pine and other timber are frequently intermingled. The trees are not in good condition, however, owing to frequent scars from fire and other destructive

agencies. The soil is largely composed of material derived from the decomposition of granite and gneiss. In many parts of the basin it has a thick layer of humus and is very fertile; in other parts, however, a clay is formed which is impervious to water and not well suited to agriculture. The soil in the former places will not withstand the action of flowing water, and where the forests have been cut considerable washing of the top soil can be observed. In the lower part of the drainage basin the soil is sandy and is largely devoted to agriculture, the chief crops being cotton, sugar cane, and sweet potatoes.

The Saluda is largely outside of the mountain region, its headwaters only being on the slopes of the Blue Ridge. For this reason it is perhaps not of as great importance in the investigation of the proposed Southern Appalachian Park as the streams which rise and flow for many miles through the mountains. The preservation of the forests, however, is of the greatest importance, owing to the nonresistant character of the soil and the danger of heavy wash and floods.

NORTH SALUDA RIVER.

This stream rises on the western slope of Rocky Spur and Hogback Mountain, at an elevation of 2,600 feet. It is 25 miles long and flows in a general southwesterly direction, joining the Middle Saluda about 3 miles below the confluence of that stream with the South Saluda. The elevation at the junction is about 980 feet. The average fall per mile is therefore about 65 feet. Most of this fall, however, is on the upper portion of the stream, the average fall per mile for a distance of 20 miles above the mouth of the North Saluda being only about 25 feet.

Around the headwaters of the stream about 15 per cent of the watershed has been cleared. The western sides of Rocky Spur, Hogback Mountain, and Glassy Mountain and the eastern slopes of the Saluda Mountains have been very little cleared, while the southern slopes of the latter mountains are especially well wooded. No lumbering is being done in this section, and the land cleared for farming purposes is proportionately small. As a natural consequence of its forested basin the waters of the stream are never very muddy, although they are said to contain more sediment than either the Middle Saluda or the South Saluda.

After leaving the mountains the flood plain of the river broadens, and the wide, flat bottoms are given up largely to agriculture, the chief crop being corn, although considerable cotton is raised. Discharge measurements were taken on the North Saluda 2 miles below Humphries's store, at Lima, and at Marietta, with the results given in the table on page 138. The river has an average annual fluctuation of 10 feet.

Fall Creek, a small tributary flowing into the North Saluda about midway between Humphries's store and Lima, has a fall of about 120 feet to the mile and a mean discharge of 6 or 8 second-feet.

MIDDLE SALUDA RIVER.

The Middle Saluda rises in Jones Gap, in the Blue Ridge, on the North Carolina–South Carolina boundary line, at an elevation of 3,000 feet. Its total length is about 20 miles; the elevation at its mouth 990 feet. It has an average fall of 100 feet to the mile, but, as in the case of the North Saluda, the fall is much greater in its upper portion than in its lower course, the average fall for 10 miles above its mouth being only 11.6 feet per mile.

The drainage conditions affecting the flow of the stream are similar to those of the North Saluda. Its flood plain is quite broad below Riverview and is under cultivation. The soil in the river bottoms is rich and loamy and black in color, while the hills are covered with a deep, rather rich, light-red soil. A large amount of cotton is raised around Marietta, and below that place cotton constitutes the chief crop.

The water power is better than that of the North Saluda. The Cleveland mill, on Mill Creek, a tributary from the east, is a small sawmill and gristmill having a working head of about 12 feet. Below it shoals are quite frequent on the main stream. Opposite Marietta there is a shoal a half mile long, called Long Shoal. The fall is possibly 10 feet in 200 feet. Two miles below the Long Shoal there is a sawmill and gristmill having a dam about 6 feet high and a working head of 12 or 15 feet. The average annual fluctuation of the Middle Saluda is 9 feet.

SOUTH SALUDA RIVER.

This branch has a total length of 30 miles. It rises just behind Pinnacle Mountain, at an elevation of 2,700 feet. The difference in elevation between its head and mouth is 1,720 feet, the average fall per mile 57 feet. It has one large tributary, viz, Oolenoy (sometimes called Illinois) Creek, a stream about 10 miles long, with an average fall of 30 feet to the mile below Sunnydale. It has wide and fertile bottom lands, planted chiefly in corn. The upper watersheds of both South Saluda River and Oolenoy Creek have been practically untouched by the woodman's ax.

The only fall observed on the South Saluda was 8 miles west of the Cleveland mill, just below the bend in the stream. The fall there is 30 feet in 100 feet, but the building space is rather cramped. The flood plain of the river varies in width from 50 to 200 yards, and the soil is deep and rich.

The scenic features of the region surrounding the headwaters of the South Saluda and the Middle Saluda are remarkably striking.

The southern slopes of the Blue Ridge are very steep. Table Rock, a mountain with an elevation of 3,157 feet, is surrounded by an escarpment of bare rock on all sides except one, and presents a very forbidding appearance. There is a popular summer resort, owned by Furman University, on Cæsars Head Mountain.

DISCHARGE MEASUREMENTS.

During the investigation measurements were made of the North Saluda, the South Saluda, the Middle Saluda, and Fall Creek, as shown in the following table. A gaging station has been maintained on the main river at Waterloo, S. C., since August 30, 1896, the results obtained being published in the subsequent annual reports of the Survey.

Discharge measurements of Saluda River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
1901. May 24	Saluda River	Greenville, S. C	N. C. Curtis	34.5	1,594.0
1900. Sept. 7	South Saluda River.	Freeman Bridge, below mouth of Middle Saluda River.	do	14.1	223.0
Oct. 14	do	do	do	14.1	171.0
1901. May 3	do	do	E. W. Myers	12.4	469.0
1900. Sept. 7	do	2 miles above mouth of Middle Saluda River.	N. C. Curtis	6.0	188.0
Oct. 14	do	do	do	6.0	134.0
1901. May 3	do	do	E. W. Myers		290.0
1900. Sept. 7	Middle Saluda River.	1 mile above mouth	N. C. Curtis	11.75	68.0
Oct. 13	do	do	do		55.0
1901. May 2	do	do	E. W. Myers	10.3	181.0
1900. Sept. 7	North Saluda River.	Iron bridge at Marietta	N. C. Curtis	14.7	58.2
Oct. 13	do	do	do	14.17	80.0
1901. May 3	do	do	E. W. Myers	13.5	163.0
1900. Sept. 6	do	Bridge on Lima-Cleveland Mill road.	N. C. Curtis	12.9	56.1
Do	do	2 miles below Humphries's store	do	14.2	26.1
Do	Fall Creek	Bridge on road to Lima	do		[a] 15.0

[a] Estimated.

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

BROAD RIVER.

PHYSICAL FEATURES.

Broad River rises on the eastern slope of the Blue Ridge, in McDowell County, N. C., between the Swannanoa and the Edmondson mountains. It flows in a southwesterly direction through Hickory Nut Gap (see Pl. XXXIII), until it is joined by Green River, when it bends to the east and maintains that course for about 20 miles. After it is joined by the First Broad it turns abruptly to the south and crosses the North Carolina boundary line near Shelby. The river and its tributaries were examined as far down as Dellinger, S. C., about 1 mile from the State boundary line. Its drainage area in North Carolina includes portions of Henderson, Polk, Rutherford, McDowell, and Cleveland counties, and aggregates 1,400 square miles. Its total drainage area is 4,950 square miles.

Three important branch streams contribute their waters to those of Broad River, two entering from the north, called First Broad and Second Broad, and the other entering from the west and known as Green River. These streams drain an area of the Blue Ridge and adjacent ridges extending to the State boundary line in Henderson County to and including the south side of the South Mountains in Rutherford and Cleveland counties. Pool Creek, a small branch from the south, discharging 6 or 8 cubic feet per second, is interesting on account of the pools which have been formed through the action of the water. There are three of these pools, each resembling a huge auger hole 6 feet in diameter. No definite information was obtainable as to their depths. Buffalo Creek, a small stream rising on the east side of the Bald Mountains and entering Broad River from the north, has a wide flood plain near its mouth and an average rise of 6 feet. Just above Ayr it is said to have a fall of 30 feet. This stream was not visited.

After leaving Batcave, where it is joined by Hickory Nut Creek (a typical headwater tributary shown in Pl. XXXIV), Broad River flows for 6 miles through a gorge which is justly famous for the grandeur of its scenery and the number of interesting natural curiosities. The mountains rise abruptly on either side to a height of 200 feet above the stream bed, and for about three-fourths of the way up are clothed with a thick forest growth. The upper side of each slope is guarded by an escarpment of granite absolutely bare of all verdure. This wall of rock varies in height from 200 to 1,000 feet. On the northeast corner of Sugarloaf Mountain and overlooking the gorge is a perpendicular mass of rock called Chimney Rock, which is detached from the face of the mountain and stands a massive silhouette against the sky. Its greatest height is 213 feet, its diameter at the summit 60

feet. The top of the rock is reached by a wooden stairway. A half mile directly west of Chimney Rock are the falls of Fall Creek, which are said to have a sheer drop of several hundred feet, but the quantity of water is insufficient for water power. On the left bank of the river is a mountain known as Old Rumbling Bald.

The region possesses a great variety of scenic and agricultural features. The soil is generally loose and porous. The headwaters of Broad and Green rivers rise among the high peaks of the Blue Ridge, and after winding their way through gaps and gorges finally emerge and flow through a region of low, rolling hills. There is very little bottom land along any of the larger tributaries. The only extensive stretches observed were along the lower portions of Whiteoak Creek and Cove Creek. The entire region is very healthy. The country east of the Blue Ridge, including the watershed and the drainage basin of Broad and Green rivers, is fair for farming purposes, though the soil is not especially rich. The chief crops in this section appear to be corn and wheat.

RAINFALL.

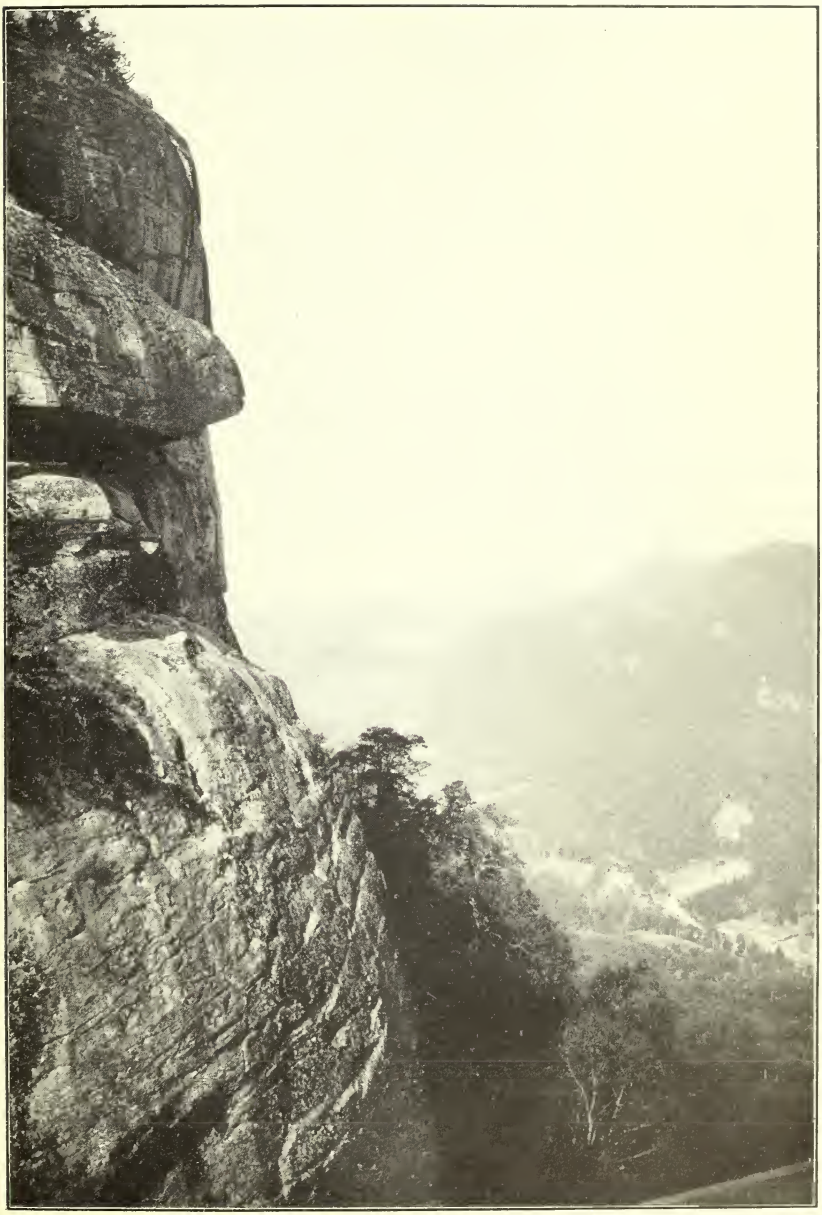
The rainfall in the basin of Broad River is approximately 51 inches, distributed throughout the year as follows: Spring, 13 inches; summer, 13 inches; autumn, 10 inches; and winter, 15 inches. The rainfall in the region above the headwaters is, however, probably much greater than this. The bed of the stream is of rock, clay, sand, or gravel, but in many places the banks are low and the bottoms are overflowed during freshets.

FORESTS.

The timbered areas are comparatively small. Very little clearing has been done around the headwaters of either Broad River or Green River. The drainage basins of the Broad proper, the First Broad, and the Second Broad contain little valuable timber. For 2 miles above Batcave the land has been considerably cleared for farming, corn being the chief crop. The upper watershed of Reedy Patch Creek has been entirely cleared, and extensive clearing has been done around the heads of Cove, Maple, and Mountain creeks.

MINERALS.

The mineral wealth of the Broad River region is considerable. Deposits of gold are found about the headwaters of the First Broad, the Second Broad, and Silver and Muddy creeks, and these have been worked in a crude way since 1830. Several mines are also being worked on the flanks of the South Mountains, the ore being a



HICKORY NUT GAP FROM CHIMNEY ROCK, NORTH CAROLINA.

HICKORY NUT CREEK, NORTH CAROLINA.

very good grade of sulphuret. Here the famous Bechtler dollar was formerly coined. Monazite is extensively mined and shipped to the North and to foreign countries. Copper, corundum, and tin are among the minerals obtained.

DISCHARGE MEASUREMENTS.

During the investigation two gaging stations were established on Broad River, one at Dellinger, S. C., and the other near Alston, S. C., and measurements were made at these stations and at other places on the main river, as shown in the following table. Measurements of the tributary streams are given in the table on page 143.

Discharge measurements of Broad River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-ft.*
Feb. 26	Near Alston, S. C	E. W. Myers	5.40	8,913.0
Apr. 18	do	do	6.28	
Apr. 20	do	do	13.60	44,456.0
May 22	do	do	3.40	4,406.0
July 5	do	do	4.25	5,962.0
Aug. 17	do	do	2.80	2,840.0
1901.				
May 7	Near Blacksburg, S. C	do	2.50	2,418.0
1900.				
Aug. 30	At Dellinger, S. C	do	0.80	1,430.0
Aug. 28	Ford 1 mile above mouth of Second Broad River, North Carolina.	H. A. Pressey	5.95	649.0
Aug. 25	McClure's bridge, North Carolina	N. C. Curtis	23.43	220.0
Oct. 18	do	do	22.67	434.0
1901.				
Aug. 9	do	do	20.8	683.5
1900.				
Aug. 22	Near mouth of Buffalo Creek, North Carolina.	do	15.2	57.1
Oct. 6	do	do	14.59	145.4
1901.				
Aug. 10	Near Chimney Rock, N. C	do	14.1	247.6
1900.				
Aug. 21	Bridge at Batcave, N. C	do		50.1
Do	do	do	10.15	48.0
Oct. 6	do	do	10.45	62.4

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of all the measurements in the above table except those made near Alston and at Dellinger, where bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In the latter case, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

The average annual fluctuation of the river at its mouth and near Buffalo Creek is 10 feet; at Batcave it is 8 feet.

WATER POWERS.

Broad River rises at an elevation of 3,100 feet. The elevation at the junction of Broad and Green rivers is about 780 feet. The total length of this portion of the stream is about 40 miles and the difference in elevation 2,320 feet, making the average fall per mile 58 feet. The average fall per mile from its head to its junction with Hickory Nut Creek, at Batcave, is 125 feet. From Batcave to a half mile below the mouth of Pool Creek the fall is also 125 feet per mile, but from that point to the mouth of Green River the fall is only 8 feet to the mile. As far down as Batcave the stream has a flood plain of about 75 yards average width, with no very steep slopes on either side. Hickory Nut Creek, a small stream entering the river just above the mouth of Reedy Patch Creek, has an average fall of 175 feet per mile, and the latter stream a fall of 150 feet per mile.

The water power of the upper section of the river is excellent and has been very little developed. Rock ledges are numerous, and falls of 8 feet in 100 feet frequently occur. The only obstacle is the absence of good building sites. There are three mills between Batcave and Pool Creek, each having a working head of about 10 feet.

The distance between Poors Ford and Dellinger is 25 miles. The water powers, descending the stream, are, briefly, as follows: (1) Big Island Ford Shoals, 1½ miles below Poors Ford, having a vertical fall of 3 feet and a slope of probably 6 or 7 feet in 400 yards, with good rock bottom and natural abutments; (2) Durham Shoals, 6 miles below the mouth of Second Broad River, with a vertical fall of 7 feet, which could be increased to 12 feet at the wheel, and with excellent foundations for a dam and building; (3) Palmers Shoals, 1 mile below the mouth of First Broad River, with a fall of about 18 feet in a half mile (the south bank at these shoals is nearly level, but the rock cliff juts out prominently on the north bank); and (4) Hopper and Blanton shoals, where the river makes a horseshoe bend and the difference in elevation across the neck is said to be 30 feet, the short shoal on the lower side of the neck being known as the Hopper Shoal and the one on the upper side as the Blanton Shoal. The latter power could be developed by piercing the neck of the tunnel and damming the water at the Blanton Shoal.

TRIBUTARIES OF BROAD RIVER.

DISCHARGE MEASUREMENTS.

During the investigation the following measurements were made of the principal tributaries of Broad River, in order upstream:

Discharge measurements of tributaries of Broad River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
1901.					
May 24	Enoree River	Greenville, S. C	N. C. Curtis	7.7	160.0
Do	Tiger River	14 miles east of Greenville	do	19.5	174.0
May 25	Pacolet River	Clifton, S. C	do	13.1	900.0
1900.					
Aug. 30	First Broad River	Near mouth	do	17.7	285.3
Oct. 10	do	do	do	16.2	266.4
Aug. 23	Puzzle Creek	do	do	6.70	10.0
Aug. 24	Robersons Creek	At mouth	do		24.0
Aug. 23	Hollins Creek	do	do	5.8	14.3
Do	Cathey Creek	do	do	3.35	42.0
Aug. 24	Cane Creek	1 mile above mouth	do	5.43	17.0
Do	Second Broad River.	Bridge on Rutherfordton-Morganton road.	do	7.35	55.0
Oct. 4	do	do	do	7.00	64.0
1901.					
Aug. 13	do	Iron bridge near Bostic Station	do	23.45	273.3
1900.					
Aug. 23	do	1½ miles east of Forest City	do	20.8	153.3
Oct. 5	do	do	do	20.32	188.3
Aug. 31	Whiteoak Creek	One-half mile above mouth	do	4.65	64.0
Sept. 3	Cove Creek	Near mouth	do	5.40	19.2
Do	Green River	Near Saluda, on Howard Gap road	do	17.7	74.1
Aug. 25	do	Cox's bridge	do	22.9	299.0
Oct. 8	do	do	do	22.6	255.4
1901.					
Aug. 9	do	do	do	21.0	833.2
Aug. 25	Maple Creek	Near mouth	do	7.70	8.4
Do	Mountain Creek	do	do	6.83	55.3
Oct. 8	do	do	do	6.48	70.2
Aug. 22	Cove Creek	Bridge at Rutherfordton road	do	18.65	69.3
Oct. 6	do	do	do	18.16	86.0
Aug. 22	Buffalo Creek	15 yards below main ford	do	4.10	17.0
Aug. 21	Reedy Patch Creek.	At mouth	do	5.75	13.0
Do	Hickory Nut Creek.	do	do	4.80	15.2

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

Brief descriptions of the drainage basins and water powers of the three largest tributaries are given on the following pages.

FIRST BROAD RIVER.

This tributary rises on the southern slopes of the South Mountains, in the northern part of Cleveland and Rutherford counties, N. C., and flowing south joins Broad River about 8 miles south of Shelby, N. C. It drains an area of 302 square miles. The fall between the

crossing of the railroad from Shelby to Rutherfordton and the mouth of the stream is about 105 feet, or at the rate of 8 feet per mile. The width of the stream at its mouth is about 90 feet.

The water powers on the First Broad are as follows: Ten miles north of Shelby and 3 miles north of the Double Shoals, where is located Cleveland cotton mill No. 2, which contains 4,224 spindles and is run by water power exclusively, a fall of 13 feet being utilized. At the Double Shoals there is a cotton factory which contains 2,000 spindles run by water power. The dam is 9 feet high, giving a total fall of 15 feet. Three miles southwest of Shelby are the Lauraglen cotton mills, containing 3,500 spindles operated entirely by water power. The dam is 14 feet high and 200 feet long, the fall of water at the mill 15 feet. Chambers's gristmill, still farther downstream, utilizes a fall of 9 feet, though more is available—the stream at this point will probably afford 7 or 8 horsepower per foot of fall in the low season of dry years. Stices's Shoal, about 4 miles from the mouth of the river, has a natural fall of 6 feet in a distance of 80 feet over a smooth rock bed, with considerable fall below. By the construction of a dam across the upper part of this shoal the fall could be increased still more. The Buck McSwain Shoal is about 1 mile above the mouth of the river, and has a natural fall of 3 feet in 150 yards.

SECOND BROAD RIVER.

This stream rises on the southern slopes of the South Mountains, in McDowell County, N. C., about 10 miles directly south of Marion. It flows in a southerly direction, meeting Broad River about 8 miles below the confluence of Broad and Green rivers. It drains an area of 193 square miles, and has a total length of about 50 miles. The elevation of its headwaters is 1,500 feet, of its mouth about 700 feet, giving an average fall per mile of 16 feet.

Comparatively little clearing has been done around the headwaters of either Second Broad River or Cove Creek, a tributary of Broad River which rises near the Second Broad and drains a considerable portion of the southern slopes of the South Mountains. The proportion of cleared land here is estimated to be about 10 per cent of the entire area. Lower down, however, along Cathey and Robersons creeks, the amount of cleared land is much greater, probably 50 or 60 per cent of the whole. After leaving the South Mountains the river flows through a region of low, rolling foothills. The timbered areas are thinly covered, the trees being chiefly pines and scrub oaks. The soil is rather compact, of a light-yellow color, and not particularly rich, and permits fairly good roads to be constructed without much difficulty.

Rutherfordton, the county seat of Rutherford County, about 6 miles west of the Second Broad, is on the western boundary of the cotton belt. The farming lands of Cleveland County and the eastern

half of Rutherford County are mainly devoted to the production of cotton. Some sorghum cane also is raised, and the farmers usually make enough molasses for their own consumption. As the headwaters of the Second Broad and Cove Creek are approached the soil increases in fertility. The Cove Creek Bottoms are especially adapted to the production of corn, and along the slopes of the South Mountains tobacco is easily grown. The climate of the region is salubrious, and very little sickness prevails at any season of the year.

The waters of the First Broad and the Second Broad are never clear, even after protracted droughts, but are a sort of light-brown or yellow-ochre color. This is due to the character of the soil and to the extensive clearing which the watersheds have undergone. The beds of both streams are sandy except where rock shoals occur.

There are four cotton mills in operation in the Second Broad River region. The motive power of two of them is supplied by steam and of the other two by water. One of the steam mills is at Rutherfordton and the other at Forest City. The two water-power mills are known as Henrietta No. 1 and Henrietta No. 2. The former is 6 miles above the mouth of the river, at High Shoals, the latter about 7 miles above the mouth, at Caroleen. Both factories are connected with the Seaboard Air Line Railroad by branch lines. Henrietta mill No. 2 occupies the shoals formerly known as Harrells Shoals and Old Burnt Factory Shoals. A masonry dam about 24 feet in height gives a fall at the wheel of 29 feet. The natural fall of the shoals is 18 feet. The mill contains 35,000 spindles and 1,000 looms. At Henrietta mill No. 1 the natural fall is 23 feet, but a stone dam, slightly curving upstream, 17.8 feet high, gives a fall at the wheel of 32 feet. This dam is 200 feet long. The race is 300 feet long, 35 feet wide, and 10 feet deep. The mill operates 25,000 spindles and 1,000 looms. Both factories have auxiliary steam plants, and seem to have been extremely successful and profitable to their owners. The cotton used is raised in the immediate vicinity and hauled to the mills on wagons. About 2 miles from the mouth of the river the stream makes a long curve, the hillsides closing in very close to either bank. A site has been surveyed here for a large mill, and land has been cleared and construction begun. The natural fall between this site and Henrietta mill No. 1 is about 40 feet. A dam 23 feet high is to be built. No race is to be constructed, but the wheels are to be located at the dam. The fall below the shoals is abrupt for a short distance, and the waste water will flow off readily. The building site is fairly good. This dam will destroy the water power of Tumbling Shoals, 3 miles above the mouth of the river.

GREEN RIVER.

Green River rises in Henderson County, near the Transylvania County boundary line, on the northwestern slopes of the Saluda Moun-

tains. The elevation of its headwaters is 2,900 feet, of its mouth 780 feet, the difference in elevation being 2,120 feet. The total length of the river is about 45 miles, making the average fall per mile about 47 feet. The distance from its head to the point where it emerges from the Blue Ridge is 23 miles, and the difference in elevation between the two points 1,800 feet, making the average fall per mile in that section 78 feet. The length of the remaining section is 22 miles and the difference in elevation 320 feet, making the average fall per mile only 15 feet. The drainage area is 198 square miles.

Along the upper portion of the river the mountain slopes shut in very close, and the timber on the watersheds is practically untouched. Consequently the flow of the stream is constant and the water always clear and cold. The scenery up Green River Cove and around Saluda while beautiful is not remarkably grand. The two most conspicuous mountain peaks are Whiteoak and Tryon. The latter has an elevation of about 3,200 feet.

Between Zirconia and the mouth of Cove Creek the river flows in a narrow gorge. The water power of this section is excellent, but building sites are scarce. The two water powers which are considered among the best on the stream were visited. The first of these, the Pot Shoals, is about 2 miles below the Southern Railway bridge. The fall consists of a drop of 8 feet and a total fall of possibly 30 feet in 100 feet. There is a fairly good site for a building here and excellent facilities for constructing a dam. The next power is at The Narrows, about 4 miles below the Pot Shoals. Here the stream is forced to pass through a narrow and rocky channel 7 feet wide and 50 feet long. The fall is about 10 feet in 100 feet. Building facilities are poor. Another power on the river, known as the falls of Green River, is not so well located as are the Pot Shoals. Here "the fall is about 30 feet in 100 feet, preceded by rapids for three-eighths of a mile, making a total fall of 45 feet. The banks are rocky and very steep, so that building facilities are not good." On the whole, the water powers of Green River are better than those of the Upper Broad, but they are not so accessible, and the building sites are poor. The average annual fluctuation of the river at its mouth is 11 feet; near Saluda it is 9 feet.

The healthfulness of the Green River region is unexcelled. Saluda and Tryon, situated on the Asheville and Spartanburg division of the Southern Railway, are popular summer and winter resorts.

Great expectations are entertained of the deposits of zircon in the valley of Green River.

The side streams flowing into Green River are mostly short, but have heavy falls. Whiteoak Creek is the only tributary of importance. Its fall, however, is small, but it has a very wide flood plain. The bottom land is well cultivated, mostly in corn. The soil is loamy and rich. The average fall is about 12 feet to the mile; the average annual fluctuation 10 feet.

FALLS ON UPPER CATAWBA RIVER, NORTH CAROLINA.

CATAWBA RIVER.

PHYSICAL FEATURES.

This river rises near the Buncombe and McDowell county line in North Carolina, and flows almost due east through McDowell and Burke counties and between Alexander and Catawba counties, where it turns to the south and finally enters South Carolina near the Mecklenburg-Gaston-York county line. After a course of about 160 miles in South Carolina it joins the Congaree to form the Santee. Below the mouth of Big Wateree Creek the river is known as Wateree River. Its drainage area in North Carolina is 3,085 square miles. Its total drainage area is 5,225 square miles.

The Catawba receives its headwaters from the southeastern slopes of the Blue Ridge, the main stream rising at the junction of the latter mountains with a spur known as the Edmondson Mountains. At Oldfort the waters of Mill Creek, with its branch, Jarrett Creek, are added to the Catawba, forming a river of considerable size. The drainage basins of these streams are decidedly mountainous, with steep, wooded slopes. The streams are swift mountain torrents, with large falls and great fluctuations of discharge. The flow at times of low water, however, is fairly large. On Catawba River above Oldfort there are precipices many feet in height, over which the river plunges in its descent toward the Piedmont Plain. (See Pl. XXXV.) In the first 6 miles of its course the river falls 1,500 feet. Below Oldfort the character of the drainage basin changes, becoming very like that of the Yadkin, described on pages 158 to 164. The valley broadens out, especially on the south side of the river, the land immediately contiguous to the stream being flat or gently rolling. The Blue Ridge is not far distant, however, extending to the northeast, with frequent ridges projecting toward the Catawba, between which flow the numerous northern branches of the stream. The tributaries from the north are Curtis, Crib, Clear, and Buck creeks, North Fork, Paddy Creek, Linville River, Cane Creek, Upper Creek, John River, and Lower Creek. These streams for the most part receive their waters from either the Blue Ridge or the Linville mountains, and in their upper courses run between parallel ridges with steep slopes heavily wooded. In their lower courses they reach the Piedmont Plain, where the fall becomes less and their valleys more open, being generally cultivated to some extent.

The river receives several tributaries from the south between the source of the stream and Morganton. The chief of these are Crooked Creek, Muddy Creek, and Silver Creek, meandering, comparatively slow-flowing streams, with a large part of their drainage areas under cultivation.

The reconnaissance of the drainage basin of Catawba River extended only from its headwaters to Morganton, N. C., that being the portion of greatest interest in connection with the studies of the proposed Southern Appalachian Park. Below Morganton the river receives a number of large tributaries and has many water powers in its course across the Piedmont Plain, but they were not visited.

RAINFALL.

The average rainfall in the basin of the Catawba is about 50 inches, distributed as follows: Spring, 12 inches; summer, 14 inches; autumn, 10 inches; and winter, 14 inches. Toward the upper part of the stream, however, the rainfall in winter increases, and is probably greater than in summer.

FORESTS.

The region of the headwaters of the Catawba and its chief branches, which flow from the steep slopes of the Blue Ridge, is heavily forested. At the foot of the mountains the timber consists of beech, poplar, linn, oak, and ash, changing to pines as the slopes are ascended, and near the summits to balsam fir. In the broad valley of the main stream a large part of the land has been cleared and is now used for agricultural purposes. The soil is deep and fertile, the top soil being largely flood deposits of the river. When the forests are cleared from the bases of the steeper mountain slopes considerable difficulty is experienced from the washing away of the top soil, leaving only the barren subsoil or clay beneath. This wash is often so extensive as to completely destroy large areas of land. Pl. XXXVI shows the effect of deforesting areas which can not properly be protected from this agency.

The banks of the Catawba are subject to overflow during the highest floods, and great damage is often caused. It is not uncommon for a fine stretch of farming land to be completely ruined in a single day by the high waters washing away the soil down to the bottom clays or gravels. (See Pl. XXXVII, *A*.) It has been estimated that in the drainage basin of the Catawba a single flood has caused damage to the extent of a million dollars. (See Pl. XXXVII, *B*.) That these floods are checked to some extent by the forests there can be no doubt; and in the absence of other regulators, such as lakes or marshes, the forests on the mountain sides form the only protection that the people dwelling in the valleys below have from the violence of flood waters.

DISCHARGE MEASUREMENTS.

During the investigation temporary gaging stations were established on Catawba River near Morganton, on John River near Morganton, and on Linville River near Bridgewater. For several years the

A.

B.

VIEWS SHOWING HILLSIDE WASH IN VALLEY OF CATAWBA RIVER.

Survey has maintained two stations on the Catawba River—one at Catawba, N. C., and the other at Rockhill, S. C.—the results of which have been published in the annual reports. The results of all measurements made on the river during the investigation are contained in the following table; the results of measurements on the tributaries in the table on pages 151 and 152.

Discharge measurements of Catawba River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-feet.*
Feb. 21	Rockhill, S. C.	E. W. Myers	2.63	3,803
Feb. 22	do	do	5.28	16,791
Apr. 13	do	do	2.75	4,703
Apr. 21	do	do	9.07	31,610
May 21	do	do	2.42	3,703
July 4	do	do	2.86	5,623
Aug. 16	do	do	1.70	1,936
Oct. 26	do	do	3.30	8,843
1901.				
Apr. 4	do	do	9.80	33,150
Apr. 23	do	do	4.65	10,314
May 23	do	do	[a]24.15	150,783
July 20	do	do	2.00	3,822
1900.				
July 3	Catawba, N. C.	do	3.45	3,372
Aug. 14	do	do	2.10	914
Nov. 7	do	do	2.95	2,083
Dec. 18	do	do	2.59	2,139
1901.				
Mar. 29	do	N. C. Curtis	5.83	5,640
Apr. 27	do	E. W. Myers	4.37	4,354
July 25	do	do	2.95	2,805
1900.				
June 13	Near Morganton, N. C.		1.33	1,393
June 18	do		2.50	4,030
July 6	do		1.30	1,164
Aug. 8	do		0.60	558
Sept. 24	do		0.50	525
Nov. 7	do		1.50	1,374
June 28	Oldfort, N. C.	H. A. Pressey	10.10	53
Aug. 20	do	N. C. Curtis	12.70	11
Sept. 20	do	do	12.78	12

[a] Greatest flood ever known on river.

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of all the measurements in the above table except those made at Oldfort, where a bench mark was established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In the latter case, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

The following table, computed by E. W. Myers, shows the comparative minimum flows of Catawba River at the Catawba and Rockhill stations, which are about 60 miles apart, for the years 1895 to 1899. The drainage area at Catawba is 1,535 square miles and at Rockhill 2,987 square miles. Comparing this table with a similar one for Yadkin River, published in Water-Supply Paper No. 36, page 119, it will be seen that the run-off per square mile does not vary more than would be expected. The Catawba station was established in 1896, the Rockhill station in 1895.

Table showing comparative minimum flows of Catawba River at gaging stations at Catawba, N. C., and at Rockhill, S. C.

Year.	Driest month.		Mean flow for driest month.		Mean flow per square mile for driest month.		Minimum flow for year.		Minimum flow per square mile for the year.	
	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.	Rockhill.	Catawba.
			Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1895	Sept [a]		1,318		0.441		1,300		0.435	
1896	Aug	Oct	1,604	865	.54	0.56	[b] 1,330	770	.445	0.501
1897	Sept	Sept	1,817	1,017	.61	.66	[c] 1,575	[d] 850	.526	.553
1898	June	June	2,091	1,069	.70	.69	1,600	910	.535	.592
1899	Nov	Nov	2,492	1,340	.835	.873	2,300	1,220	.770	.793

[a] Seven days' record.
[b] Also in July, August, and September.
[c] Minimum occurred in January. September minimum was 1,700 second-feet, or 0.569 second-foot per square mile.
[d] Minimum in October. September minimum 900 second-feet, or 0.579 second-foot per square mile.

WATER POWERS.

Between Morganton and the mouth of Mill Creek, a distance of 50 miles, there are 197 shoals with an average fall of about 2 feet. In McDowell County the fall of the river is very great, there being in one or two cases vertical drops of 100 feet, but the channel is so narrow that the power is not of great value for development. Rock Ford Shoal, at Morganton, has a natural fall of 9½ feet in a distance of about 1,500 feet.

Although the investigation embraced only the portion of the drainage basin above Morganton, as some of the chief water powers of the river are below that place they will be mentioned in this connection. Briefly described, they are as follows:

Devil Shoal has a fall of 14 feet in a distance of 1 mile, and is well located for improvement. Horseford Shoal, 3 miles north of Hickory, has a fall of 31 feet in 2.9 miles; the power is utilized to only a limited extent. The Great Fall Shoals have a fall of 14.8 feet in a distance of 1 mile. Canoe Landing Shoal, about 2 miles above the mouth of Lower Little River, has a fall of 8.9 feet in a distance of 1.87 miles. The Lower Little River Shoals are between the upper end of Druin Island and the lower end of Three-Cornered Island, with a fall of 9.7 feet in a distance of 1.16 miles. Lookout Shoal, about 6 miles above Catawba Station, has the greatest fall of any shoal on the river in North Carolina, the descent being 54.25 feet in a distance of 3.2 miles. About 30 feet of this fall is said to occur in a distance of three-fourths of a mile. The Buffalo Shoals have a fall of 11.4 feet in a little more than a half mile; they are a short distance below the Western North Carolina Railroad crossing. Long Island Shoal, about 7 miles southeast of Catawba Station, has been improved and a cotton factory constructed to utilize the power. Monbo Shoal is utilized by a cotton mill. Beatties Ford Shoal has a fall of 13 feet in 2.38 miles, and

Cowan Ford Shoal a fall of 27 feet in a distance of 4.17 miles. Mountain Island Shoal is utilized to a small extent by a cotton factory containing 6,300 spindles and using a fall of 22.5 feet. Tuckasegee Shoal, about 9 miles above the State line, has a natural fall of 11 feet in a distance of 1 mile, and is utilized by a cotton mill of 6,000 spindles. Near the State line there are several shoals with falls of from 3 to 5 feet, some of which have been used to a limited extent, but considerable difficulty has been experienced from high water.

TRIBUTARIES OF CATAWBA RIVER.

DISCHARGE MEASUREMENTS.

During the investigation the following measurements were made of the important tributaries of the Catawba above Morganton, N. C., in order downstream:

Discharge measurements of tributaries of Catawba River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
June 28	Mill Creek	Oldfort	H. A. Pressey	3.85	85.0
Aug. 20	do	do	N. C. Curtis	6.73	27.0
Sept. 20	do	do	do		13.0
June 28	Jarrett Creek	Near Oldfort	H. A. Pressey		17.0
Do	Curtis Creek	200 feet above ford of Oldfort road.	do		82.11
Aug. 20	do	do	N. C. Curtis		16.50
June 28	Crib Creek	Near ford of main road	H. A. Pressey	4.9	28.03
Aug. 28	do	do	N. C. Curtis		10.0
June 28	Clear Creek	200 feet above ford of main road.	H. A. Pressey		25.25
Aug. 28	do	do	N. C. Curtis		12.0
June 14	Buck Creek	⅛ mile above mouth, at main ford.	H. A. Pressey		51.91
Aug. 20	do	do	N. C. Curtis	5.35	41.4
July 3	North Fork of Catawba River.	First ford above mouth	H. A. Pressey		240.2
Aug. 18	do	do	N. C. Curtis		67.3
Sept. 21	do	do	do	3.18	61.69
June 15	Turkey Cove Creek	Just above second ford	L. V. Branch	5.75	21.48
June 26	do	do	do	5.30	164.8
June 14	Muddy Creek	Bridgewater	H. A. Pressey	5.80	161.9
June 16	do	do	L. V. Branch	4.1	618.0
July 10	do	do	do	6.0	119.2
Aug. 17	do	do	N. C. Curtis	6.43	98.6
Sept. 21	do	do	do	6.34	101.7
June 14	Paddy Creek	Near Bridgewater	H. A. Pressey	11.3	19.78
June 16	do	do	L. V. Branch	5.4	203.67
July 10	do	do	do	11.55	11.5
Aug. 17	do	do	N. C. Curtis	12.35	7.0
June 21	Linville River	Linville	H. A. Pressey	14.83	21.0
June 24	do	do	do	14.23	90.22
June 14	do	Near Bridgewater		9.92	104.0
July 3	do	do		9.54	216.0
July 10	do	do		9.90	116.0
Aug. 17	do	do		10.15	78.0
Sept 21	do	do		9.8	55.0
June 14	Cane Creek	Lowest ford of main Morganton road.	H. A. Pressey	5.72	18.58
June 18	do	do	L. V. Branch	5.85	28.45
Aug. 17	do	do	N. C. Curtis	6.3	7.2
June 14	Silver Creek	Near Morganton	L. V. Branch	6.84	124.0
Aug. 10	do	do	N. C. Curtis	8.30	48.4
Sept. 24	do	do	do	8.20	56.0
1901.					
June 14	do	do	E. W. Myers	13.08	995.0

Discharge measurements of tributaries of Catawba River—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
June 13	Upper Creek	¼ mile above mouth	N. C. Curtis	2.2	182.4
July 6	do	do	L. V. Branch	2.3	50.0
Aug. 8	do	do	N. C. Curtis		85.05
Sept. 24	do	do	do		60.0
June 20	do	Ford at Henderson's mill	H. A. Pressey	12.9	20.42
Do	do	Upper Creek Falls	do		27.0
Do	Steel Creek	Footbridge 100 yards above mouth.	do	3.20	100.21
Sept. 25	John River	Collettsville	N. C. Curtis	4.77	40.0
Nov. 6	do	do	do	4.47	135.0
June 13	do	Near Morganton		2.64	465.0
June 19	do	do		3.50	1,202.0
July 6	do	do		2.63	511.0
Aug. 8	do	do		1.90	135.0
Sept. 24	do	do		1.90	148.0
Nov. 7	do	do		2.32	367.0
Sept. 25	Mulberry Creek	At mouth	N. C. Curtis	7.85	17.0
Nov. 6	do	do	do	7.95	39.0
Do	Wilson Creek	do	do	0.75	208.0
June 13	Lower Creek	2 miles above mouth	E. W. Myers	14.58	209.0
July 6	do	do	L. V. Branch		132.0
Aug. 8	do	do	N. C. Curtis		69.0
Sept. 24	do	do	do	15.38	56.0

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in above table of John River near Morganton and of Linville River near Bridgewater. In making all of the other measurements, however, in each case a bench mark was established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In these cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

The principal tributary drainage basins and water powers are briefly described on the following pages.

CENTER, CRIB, AND CLEAR CREEKS.

Of the tributaries from the north, Center, Crib, and Clear creeks have drainage areas of a similar character. There is considerable fall near their sources, which gradually becomes less as the streams are descended, the valleys broadening out and being partially cultivated. About three-fourths of the drainage areas are forest-covered. The streams are too small for extensive water-power development, but two small gristmills have been built on Crib Creek. The low-water flow of the stream is so small, however, that the mill can not be run during the dry season.

BUCK CREEK.

This creek rises in Buck Creek Gap, and has a drainage basin similar to the creeks just described, though much larger. The fall is very great along its upper course. Six miles from its mouth are the falls of Buck Creek, with a vertical drop of 12 feet. A rough and rocky highway, leading from Marion through Yancey County, follows the stream throughout its course. The scenery near the gap is very fine. Two mills have been constructed, and are run during a part of the year. Near the mouth of the creek there are some

good farms. About a quarter of a mile above the mouth the Marion-Oldfort road crosses the creek. Here measurements were made of the discharge (see table on page 151).

NORTH FORK OF CATAWBA RIVER.

This stream enters the Catawba near Marion. At its headwaters it is a mountain stream with very heavy fall, draining the narrow valley between the Blue Ridge and the Linville mountains. The mountain slopes are covered with a valuable growth of timber, practically no cutting having been done on them. About 7 miles downstream the valley broadens slightly and furnishes a very fertile soil excellent for agricultural purposes. This valley land has been cleared and is now largely in grain or grass. About three-fourths of the drainage area is still in forest. Two small combined gristmills and sawmills have been built on the stream, with falls of 6 and 8 feet. Turkey Cove Creek, a branch of the North Fork, is a mountain stream of considerable fall, with wooded slopes. The total drainage area of the North Fork is 835 square miles.

PADDY CREEK.

This creek has the same general characteristics as the other northern tributaries of the Catawba in the region. Its headwaters are on the steep slopes of the Linville Mountains, and its lower course is across the Catawba Valley. Its watershed is long and narrow, being close to Linville River on one side and flowing nearly parallel to the Catawba on the other.

LINVILLE RIVER.

This river is formed by a number of small streams which head on Grandfather and Sugar mountains and in Linville Gap. The sources of most of the streams are large springs, which are numerous throughout the region, furnishing perfectly clear and chemically pure water. Grandfather Mountain has an elevation of 5,964 feet; the heads of most of the streams rising upon its slopes are at an elevation of 5,000 feet. The elevation of Sugar Mountain is 5,289 feet, while Linville Gap, between these two high peaks, has an elevation of 4,097 feet. Four miles south of Grandfather Mountain is Grandmother Mountain, elevation 4,686 feet, upon which rises Grandmother Creek, which flows into Linville River 1 mile below the village of Linville.

The mountain slopes are steep and rocky, the small streams falling in a series of cascades. The virgin growth of timber is still on the mountain sides and extends to the summits, practically no cutting having been done. Three miles below Linville, at Pineola, there is a healthy growth of white pine, but from Linville upstream the river is above the white-pine belt, the growth changing to spruce, chestnut,

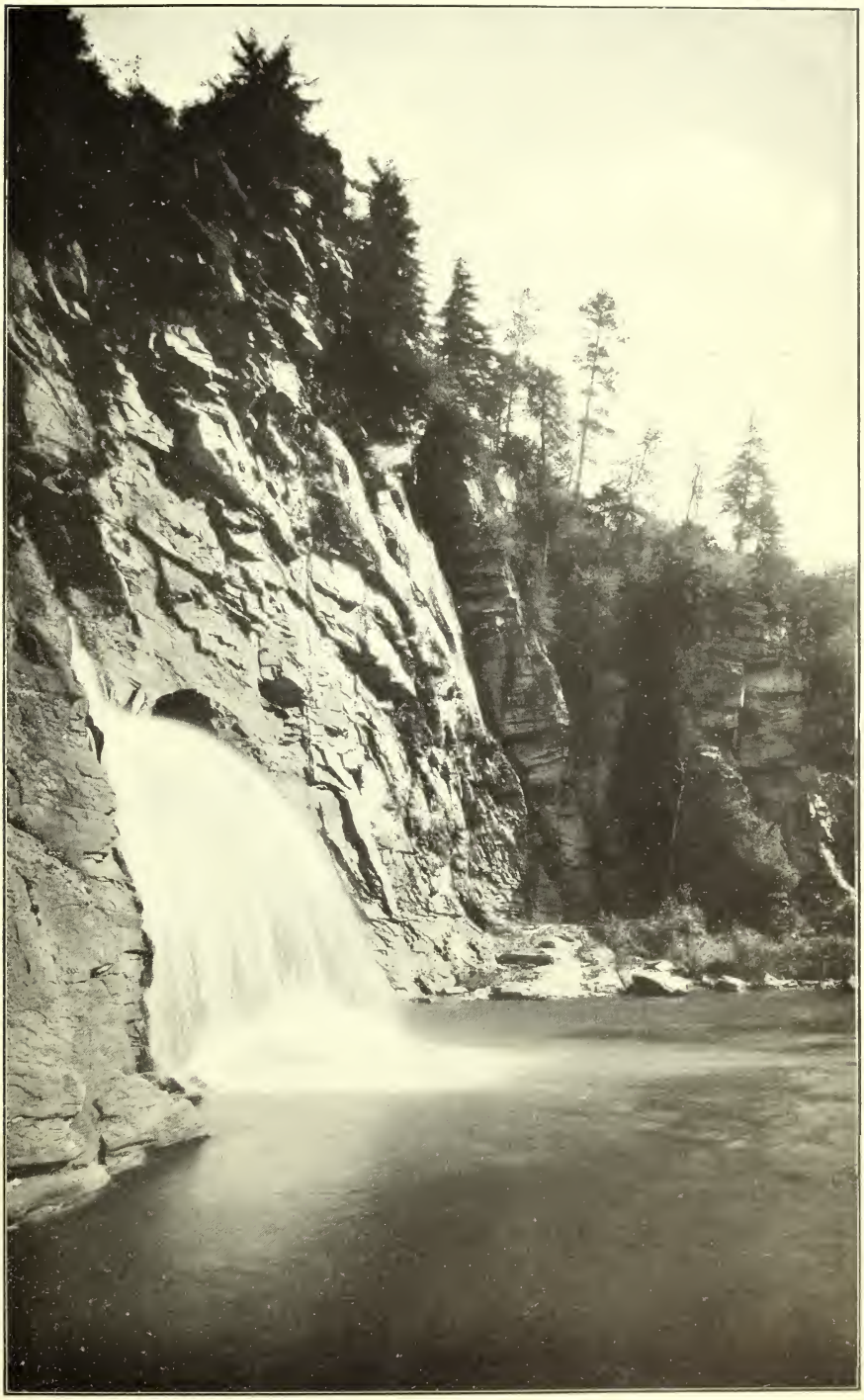
white and red oak, poplar, linn, ash, buckeye, birch, beech, cherry, and, on the highest elevations, balsam fir. The temperature is usually low, frosts having been known to occur in each month of the year.

Below Grandmother Creek the river has no tributaries of any size. From Grandfather Mountain to Linville Falls its valley is narrow, the land on both banks rising abruptly to the mountain summits, permitting only short tributaries and a narrow drainage area. Linville, a village of about thirteen houses and a summer hotel, is between the river and Grandmother Creek, on a comparatively flat area, and Pineola, 3 miles below, a village built up largely during 1900, occupies another flat section.

The falls of the Linville, located near the Mitchell-Caldwell-McDowell County line, have an aggregate fall of 90 feet in four clear leaps. The first fall is 50 feet upstream from the main fall, and is a vertical drop of 15 feet. There are then three drops in quick succession of 25, 10, and 40 feet, respectively. The water at the last drop (see Pl. XXXVIII) falls in one sheet into a still pool, from which it flows through a narrow gorge 10 miles long between Gingercake Mountain, Hawks Bill, Table Rock, and Shortoff Mountain on the east and the Linville Mountains on the west. The walls of this gorge are precipitous, in many places almost vertical, and rise to heights of from 500 to 2,000 feet. Through it the Linville has no tributaries, receiving only the water which falls on the steep slopes and the flow from the springs on the mountain sides. It may well be considered one of the greatest mountain features of the region. The high and rocky walls are so close to the river that there is no space for highway or railroad. In fact it is with the greatest difficulty that one can make his way through the chasm, jumping from rock to rock, clinging to rocky ledges, and in places where no foothold is offered on either side wading the stream. The scene is grand and inspiring, viewed either from the chasm, where immense vertical rocky cliffs rise on either hand, showing nothing beyond but the blue sky, or from the upper edge of the gorge, where one can look vertically down several hundred feet and see the rapid, sinuous stream cutting its way to the valley below.

At Linville Falls, at the upper end of the chasm, the drainage basin of the main stream and its tributaries has an area of 50 square miles. The next 10 miles of the course of the river is through the gorge. After emerging from the rocky walls of the chasm it flows for 8 or 9 miles as a comparatively quiet stream through Birch Bottom and Catawba Valley, finally joining its waters to Catawba River.

At Linville records of rainfall have been kept by the United States Weather Bureau for nearly eight years. These records show that the annual precipitation is about 46 inches, distributed as follows: Spring, 11.50 inches; summer, 13.50 inches; autumn, 9.50 inches; and winter, 11.50 inches. The climate is pleasant and very healthful, so that



LOWER FALLS OF LINVILLE RIVER, NORTH CAROLINA

numerous summer visitors take advantage of the excellent hotel accommodations at Linville, at the foot of Grandfather Mountain.

There are opportunities for development of water power on the Linville and its tributaries. On Grandmother Creek the Linville Improvement Company has built a timber-crib dam across the stream near its mouth, to form a fish and ice pond. The dam is 20 feet high, but its height could be increased and a small water-power plant installed. There is another site farther up the creek where a fall of 15 or 20 feet could be developed.

At Linville Falls, on the main stream, at the head of the gorge, considerable power could be developed, though the chasm is so narrow that there would be difficulty in finding space for buildings. From Linville Falls to the point where the river enters the flat plain of the Catawba Valley the fall of the river is large, with frequent drops of 3 or 4 feet. About 2 miles below Linville Falls, near Bynums Bluff, there is a fall of 5 feet, and 1½ miles farther down is what is known as Cascade Rock, where the river falls vertically 12 feet. From the foot of the falls to the Catawba Valley the fall of the river is about 1,800 feet. None of the power in the gorge or at the falls has been developed.

There are several small mills on the river. One mile above Linville there is a small sawmill and gristmill with an 8-foot timber dam, which has sufficient water to run throughout the year. Two miles above Linville Falls, at the mouth of Camp Creek, there is a sawmill and gristmill utilizing an 8-foot fall, and 1 mile above the falls there is a sawmill with a timber dam 10 feet high, a 46-inch turbine being used to run a circular saw. At the Franklin mill, a half mile above the falls, Pine Creek has a 10-foot fall, and power is furnished by overshot wheels and turbines. About 4 miles above the mouth of the river, at Berry's mill, an 11-foot head is utilized with a 4-foot home-made wheel, and 3½ miles lower down, at Pool's mill, a 9-foot fall is utilized for a gristmill run by a 20-inch and a 36-inch wheel. On July 3, 1900, a gage was established at the latter mill, and the miller reads the height of the river every day. Measurements of flow have also been made, the results of which are given in the table on page 151.

In ordinary years the river has a fluctuation of about 8 feet at Pool's mill, though on September 6 and 7, 1898, the water rose 18 feet in forty-eight hours. This is the highest stage known, but in 1882 there was a rise of about 17 feet.

CANE CREEK.

Cane Creek, flowing into the Catawba from the north, drains 16 square miles of comparatively flat and open country, much of which is under cultivation. There is very little fall in this stream. The measurements made are given in the table on page 151.

UPPER CREEK.

This stream, the next important tributary of the Catawba from the north, rises on Jonas Ridge and Cranberry, Cold, and Park mountains, at an elevation of about 4,000 feet. The sides of these mountains are for the most part steep and precipitous and are covered with a dense forest growth. The most common trees are chestnut, oak, white pine, and poplar. Very little of the original timber has been cut, though fires have spread over considerable areas, seriously injuring the forests. As the fires, however, were widely separated, both in time and in area, the drainage basin near the headwaters of the stream is almost entirely forest covered, either with the original timber or with a younger forest growth.

A large part of the regular flow of the creek is made up of effluents from springs, which are numerous on the mountain slopes. To this flow, however, is added the surface drainage from the mountain sides, which in the upper part of the creek reaches the stream quickly, so that during a rain the creek rises rapidly and falls soon after the rain ceases.

Throughout this and the neighboring watersheds will be found shady ravines, with springs breaking forth and adding their waters to other springs until a considerable stream is formed with a comparatively constant flow. The Piedmont Springs, 9 miles from the source of Upper Creek, have been celebrated for thirty years, and formerly many people from the Southern States visited them as a summer resort, being accommodated in a large hotel close at hand. The springs are charged with iron and soda. Though still flowing, they are not now much visited and the hotel has fallen into decay. About 2½ miles from the source of Upper Creek is Cold Water Spring, where a hotel has recently been built to accommodate summer visitors.

The fall of Upper Creek and its tributaries is very great from the headwaters down to Piedmont Springs. The two forks of the creek have a fall of 250 feet per mile to their junction. In the next mile there is a fall of 1,000 feet, largely made up of a series of small falls of from 5 to 10 feet. About one-fourth of a mile below the Cold Spring hotel there is a single fall of 90 feet. On June 20, 1900, the stream was measured a few feet above these falls, and the quantity flowing was found to be 27 second-feet. The low-water flow is probably about two-thirds that amount. The walls here are steep and rocky, with good natural abutments for a dam, though the fall is so great that the storage capacity would not be very large. About three-fourths of a mile above these falls there is a combined shingle mill, sawmill, and gristmill. An 8-foot dam has been built across the stream, giving an 18-foot head on the wheel—a Smith-Morgan turbine. A half mile farther down there is another small sawmill and gristmill. Between the main falls of Upper Creek and the gristmill there is a fall of at least 200 feet in a distance of three-fourths of a mile.

The low-water flow of the creek is quite large, owing to the many springs in its watershed and to its forested basin. From Jonas Ridge down to Joy the drainage area is completely covered with forest from the river bank to the summits of the mountains. The most common trees are chestnut-oak, white pine, and poplar. At Joy there is a small gristmill with a 6-foot timber dam, and a half mile below there is a gristmill and sawmill with a flow of about 8 feet over a timber dam, two 36-inch turbines furnishing the power. There is another gristmill on Upper Creek near the mouth of Irish Creek. From Joy to the mouth of Upper Creek the valley is wider and the hills bordering the watershed are comparatively low and flat, rising on either side about 100 feet above the stream. The hillsides are largely covered with forests, the growth extending to the banks of the creek. There are, however, open cultivated areas through the valley, the chief crops being corn and wheat. It is probable that two-thirds of the total drainage area of Upper Creek is forested.

Below Joy there are two mills—Turner's and Wakefield's. In the next mile there is a fall of about 25 feet, the ordinary high-water rise above the present stage being about 7 feet. Turner's mill is a gristmill and sawmill with a fall of about 8 feet, two 36-inch Smith-Morgan turbines being used. The 7-foot dam backs the water about a quarter of a mile. At lowest stages the water is about 6 inches lower than at the time of measurement, when the discharge was 20.42 second-feet. In 1898 there was unusually high water, the stream rising 16 feet. Three miles below Turner's mill is Caldwell's gristmill, owned by Mrs. W. C. Anderson. There is a fall of $7\frac{1}{2}$ feet here and backwater for 1 mile. There is said to be 14 horsepower available with one Smith-Morgan turbine 20 inches in diameter. At lowest stages the stream at this point falls about 4 inches below the surface elevation at the time of measurement, and at such times it has about one-third less flow. During high-water periods the rise is about 6 feet. The highest water known was about 12 feet above the surface elevation at the time of measurement.

Steel Creek.—This tributary of Upper Creek, which rises on Hawks Bill and neighboring mountains, enters the latter creek near Joy. Its drainage area has the same general characteristics as that of the upper part of Upper Creek, and its fall will average 530 feet per mile for the first 3 miles, 200 feet per mile for the next 2 miles, and 50 feet per mile the rest of the way.

JOHN RIVER.

John River, the largest tributary of the Catawba, adds its water to the latter stream about 3 miles northeast of Morganton. Its drainage area contains 213 square miles and is extremely rough and mountainous in its upper part, the topography becoming gradually more gentle as the river is descended. It receives its headwaters from the many

fine, large springs and the run-off on Grandfather Mountain and the other mountains in the region near Blowing Rock.

This drainage basin, with its fine views, its dense forests, its numerous springs, and its salubrious climate, is one of the most beautiful and delightful parts of the Southern Appalachian region. The many summer guests at the hotels at Blowing Rock and Linville are well repaid for their visit by a day spent on the summit of Grandfather Mountain, from which is obtained a most magnificent view of the great billowy sea of mountains stretching away from it in every direction. A ride over the Yonahlossee road, the finest mountain road in the South, with its frequent glimpses of river valleys and mountain peaks beyond, with its numerous little streams which dash down the mountain sides, cross the road, and leap from rock to rock in their descent to join John River or one of their tributaries far below, is a pleasure to be long remembered.

The main stream and its upper tributaries, chief among which are Mulberry and Wilson creeks, have falls of 2,000 or 3,000 feet in the first few miles of their courses. Vertical falls are frequent, especially on Wilson Creek, and considerable power could be developed. Above Collettsville, at the junction of Mulberry Creek with John River, the drainage area is rough, the valley narrow, and the mountain slopes steep and well timbered. Below the junction the valley widens considerably, and where cleared of trees it presents a splendid farming country. There are great tracts, however, which are still in timber. On the ridge to the west of the river there has been considerable prospecting for gold, and a plan has been considered of constructing a flume to carry water from Wilson Creek across John River for use in hydraulic mining.

LOWER CREEK.

Lower Creek, the next tributary of the Catawba from the north, has a comparatively flat watershed. The fall is not so great as that of the upper branches, and in every way the creek has more the nature of a stream of the Piedmont Plain.

YADKIN RIVER.

PHYSICAL FEATURES.

Yadkin River rises on the eastern slopes of the Blue Ridge, in Caldwell and Watauga counties, near Blowing Rock, N. C. Its course is almost south, until at Patterson it turns to the northeast. It was examined and gagings were made as far down as Ararat River, a large tributary from the north. In this portion of its course it flows through Caldwell and Wilkes counties and between Yadkin and Surry counties.

Beginning at Siloam, where the flood plain of the river is about three-fourths of a mile wide, the bottom land gradually widens as the head of the stream is approached, being in some places nearly 2 miles in width. The flood plain is subject to occasional overflows. Its soil is very deep and fertile, the result of washings from the mountain slopes above. The river basin between Patterson and Siloam varies in width from 5 to 25 miles. The divides which separate it from the basins of the New and the Catawba are high and steep, so that the tributary streams are not very long, but they have large falls. On the north the river is flanked by the Blue Ridge, whose highest peaks attain elevations of more than 4,000 feet. On the south, and lying closer to the stream, are the Brushy Mountains, a low ridge which in places attains an elevation of 2,000 feet.

The upper part of the valley of the Yadkin is very well wooded, and the forests, with the deep soil on the mountain sides, tend to make the flow of the stream more constant than might be expected in the absence of lakes or marshes to act as regulators. The highest flood of which there is any record extant was in 1878, when the river rose 23 feet. The floods are of short duration, generally subsiding in from thirty-six to forty-eight hours. It is said that twenty-five years ago high floods very rarely occurred, and their frequency now is accounted for by the clearing of the hills and the removal of obstructions from the river.[a] The lowlands are more frequently overflowed than formerly, and more damage is done to the crops. The annual rainfall in the upper valley varies from 44 to 50 inches.

Between Patterson and Wilkesboro the lowlands are in places a mile or more in width and are exceedingly fertile. This region is known as Happy Valley, and is considered to be among the finest agricultural sections of the State. The chief products are corn, wheat, tobacco, cotton, cane, and fruits. The corn and wheat raised are especially good. Pasture land in the immediate vicinity is poor, but along the slopes of the Blue Ridge grazing is better and considerable hay is produced. The climate is salubrious. The Wilkesboro division of the Southern Railway passes up the north banks of the Yadkin as far as the town of North Wilkesboro. The only two towns of any importance along this part of the stream are Elkin and Wilkesboro. Both are growing rapidly and give promise of continual development.

The well-defined river basin of the Yadkin is marked by an apparently unbroken valley floor lying at an average elevation of 1,200 feet. This floor, which rises by a gentle inclination from about 1,100 feet along the river to 1,400 feet at the bases of the bounding ranges, can be seen to best advantage when standing on the steeper slopes of the mountains, as, for instance, on the road from Lambsburg to Cold Spring, in the northern part of Surry County. As soon as one approaches the tributaries or the river itself, it is evident that the valley floor is not continuous, but that it has been deeply trenched by

[a] Ann. Rept. Chief of Engineers U. S. A., 1878, p. 628.

nearly all of the streams belonging to this portion of the Yadkin river system. The trench now occupied by the main river is from 300 feet to 400 feet below the general level of the valley, and varies in width from a half mile to a mile and a quarter. The width of the trench is clearly influenced by varying resistance in the rock series crossed by the stream; the depth, however, seems to increase uniformly downstream, without relation to rock resistance. The bottom of the main trench is covered with alluvial sands, gravels, loams, or clay to a depth of from 15 to 20 feet. Through the bottoms thus formed the river pursues a meandering course, being sunk about 10 feet below the general level of the valley floor at Siloam and not more than 5 feet below in the vicinity of Patterson's mill.

The trenches cut by the tributary streams are narrower than the main trench, have steeper bounding slopes, which are sometimes precipitous, and have narrower bottoms, which often extend far up the streams. Near their mouths the tributary valleys are very narrow, their channels steep, and usually a number of low cascades over resistant layers characterize the debouchments of the streams upon the broader bottoms of the river.

Along the steep slopes of the trench of the main stream, and overlooking the lower bottoms, are two sets of river terraces, which have been partially cut out of the deeply decayed gneissic rocks and partially built up of stratified gravels, sands, and clays. These two terraces are at elevations of 20 and 60 feet above the lower bottoms. In places traces of a third terrace, at about 100 feet, can be seen. Deposits similar in character and form can be found in the tributary gorges, usually at the 100-foot elevation.

SOILS.

In general the rocks of the region are schists of moderate compactness, with gneissic and slaty bands in the vicinity of Blowing Rock. Near Mount Airy the metamorphic crystallines seem to have been cut by compact granitic rocks, which withstand weathering much better than the surrounding formation, and thus have formed low hills standing above the general level (1,200 feet) of the valley floor. The granitic rocks on disintegrating produce clays and sands; but the areas covered by the resulting soils are small. The metamorphic rocks generally produce clayey subsoils, with a not very porous top soil. In some localities an unusual amount of quartz in the rocks has resulted in the production of sandy soils. Thus the soils of the valley floor are generally rather heavy, with an impervious subsoil. Consequently neither heavy rains nor the average moderate precipitation penetrates to a great depth. Instead the water gathers into surface rills and rapidly finds its way into the streams, at the same time carrying with it a large portion of the looser surface soil.

The nearly level elevated valley floor has been almost wholly cleared of timber. In it areas of remarkable fertility occur at inter-

vals. These have been extended in size and in depth by the wash from the mountain sides. The soil of the slopes on the north side of the stream is largely siliceous and is well mixed with humus and vegetable mold, affording rich pasture and farm lands. The soil of the mountain slopes on the south side of the river is shallow and comparatively poor.

FORESTS.

The forest growth consists chiefly of oak, chestnut, poplar, and linn, with some pine, and with occasional patches of hemlock. Near the railroad considerable cutting of the best trees has been done, but in many parts of the area the timber is practically untouched. Considerable damage has also been caused by forest fires, though in most places the injury from this cause has not been serious or permanent.

DISCHARGE MEASUREMENTS.

During the investigation the following measurements were made of the river at various localities along its course:

Discharge measurements of Yadkin River.

Date.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.			*Feet.*	*Sec.-feet.*
June 20	Second ford below Patterson's mill	N. C. Curtis and Cleveland Abbe, jr.	13.30	182.0
July 14	do	do	13.50	100.3
Aug. 7	do	do	13.40	76.2
Sept. 26	do	do	13.53	43.0
June 21	Wilkesboro	do	26.73	780.0
June 23	do	do	26.14	1,737.0
July 4	do	do	26.83	663.0
July 12	do	do	27.05	488.2
Aug. 6	do	do	27.20	386.0
Oct. 1	do	do	27.20	369.1
Nov. 4	do	do	26.22	1,331.0
1901.				
June 8	do	do	25.81	1,762.0
June 14	do	do	16.50	11,667.0
June 15	do	do	14.22	12,582.0
June 18	do	do	23.80	3,727.0
1900.				
July 11	Siloam	do	2.90	1,367.0
Aug. 3	do	do	2.60	1,218.0
Oct. 31	do	do	3.10	1,469.0

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table at Siloam. In making all of the other measurements, however, in each case a bench mark was established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In these cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

For several years the Survey has maintained a gaging station on Yadkin River at Salisbury, also one at Norwood, both farther downstream than the present investigation extended, the results of which have been published in the annual reports. The station at Norwood was discontinued in January, 1900.

WATER POWERS.

Between Patterson's mill and the town of Patterson, about 4 miles farther upstream, Yadkin River is a meandering stream, with slight fall, occupying a wide, terraced trench about 80 feet below the general level of the trenched valley floor already described. Although there are many shoals with gravelly bottoms between Patterson and the mouth of Little Ararat River, there are no good water powers, because of the broad, alluvium-lined valley, which offers no anchorage for dams; nor are there any sharp falls or even important rapids sufficiently high to furnish useful power. About 1 mile above Brown's ford, 4 miles west of Wilkesboro, what seem to be gravelly shoals in the river accompany a fall in the channel of 5 feet within a quarter of a mile. The bottom lands on the north bank of the river at this place are only 200 feet wide. On the south side, however, they are somewhat wider and seem to afford poorer holding ground. Again, about 3 miles above Ronda the river runs at the bottom of a narrow, rock-ribbed trench, and its channel is cut across by rough ledges of hornblende-schist. This locality, with a channel fall of 5 or 6 feet, seems to be the best on the whole stretch of the main stream, having a good foundation for a dam and natural abutments.

There are no mills on the main stream between Patterson's mill and Siloam. At Patterson, 4 miles upstream from the mill mentioned, there are two mills. The first one, a cotton mill, has a fall of about 10 feet. The other one, a few hundred yards upstream, is a woolen factory operated during the greater part of the year by water power, but having an auxiliary steam plant for use during unusually low water. This mill uses a fall of 25 feet, obtained by sluicing the water 200 yards from a 15-foot dam.

Above Patterson the river occupies a narrow, rock-walled gorge, affording many good powers, though a number are at present inaccessible. About 1 mile above the woolen mill and sawmill just mentioned the whole volume of the river crosses Ripshin Mountain through a narrow water gap floored and flanked to a great height by firm gneiss and schist. The channel at this point has a drop of certainly 5 feet within half as many rods, and a dam 100 feet long and 10 feet wide would completely flood broad meadow lands to a distance of a mile upstream. About 1½ miles upstream from this gap through Ripshin Mountain a small mill has been built to utilize a fall of 10 feet, and on Mill Fork, one-fourth mile above its confluence with the Yadkin, another mill, with an 8-foot fall, has been established, while about 1 mile above Kirby Gap this same stream (Mill Fork) has an almost perpendicular fall which is estimated to be 250 feet.

The following table contains interesting data regarding the elevation, fall, etc., of the river in various portions of its course above the mouth of Ararat River:

Elevation, fall, etc., of Yadkin River above Ararat River.

Place.	Distance from Siloam.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Average annual fluctuation.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*
Mouth of Ararat River		798				6
Wilkesboro	50	928	50	130	2.6	7
Patterson	82	1,250	32	322	10.06	5
Head of stream	95	3,500	13	2,250	173.07	

Above its junction with Mill Creek the river pursues a winding course, flowing at the bottom of a very deep and narrow gorge, with an average fall of about 50 feet to the mile.

Below Ararat River the valley of the Yadkin averages 50 miles in width, much of it composed of fertile bottom lands. At several places, however, the hills close in upon the river, confining it between steep and rocky banks. In this lower portion of its course there are many places where water power could economically be developed. The following table gives the locations of the principal powers:

Summary of water powers on Yadkin River.[a]

Locality.	Distance from State line.	Drainage area.	Total fall.		Gross horsepower available.			Remarks.
			Height.	Length of shoal.	Minimum.	Minimum average for the low season.	Average for the low season of average dry years.	
	Miles.	*Sq. mi.*	*Feet.*	*Feet.*				
Bluitts Falls	12.0	6,650	9.00	1,000	1,500	1,900	2,170	
Grassy Island Shoal	13.0	6,624	36.00	[b] 4.5	5,970	7,600	8,680	
Swift Island Shoal	42.0	4,323	18.00	[b] 2.5	1,942	2,476	2,796	
Gunsmith Shoal	57.5	4,300	9.50	2,500	1,020	1,300	1,470	
Narrows	60.0	3,938	91.00	[b] 5	8,954	11,375	12,922	
Bull Island Shoal	65.0	3,800	29.00	[b] 2	2,854	3,625	4,118	Undeveloped.
Penningtons Shoal	67.0	3,900	74.00	[b] 4.5				
Milledgeville Shoal	70.0	3,500	14.00	[b] 0.7	1,378	1,750	1,988	
Motts Falls	72.3	3,400	13.50	[b] 0.8				Do.
Bald Mountain Shoal	73.8	3,300	8.50	[b] 0.5				Do.
Flat Swamp Mountain Shoal.	78.3	3,000	10.20	[b] 6.5				Do.
Fries Manufacturing and Power Co.	131.5	1,865	10.00	1,600				Rock bottom.
Langenhour & Neason's dam.	138.5	1,827	4.57		220	280	325	Do.
Shallow Ford Shoal	145.0	1,812	7.89	5,560	375	485	550	Rock and gravel bottom.
Shoal above Shores Island.	155.2	1,633	7.73	9,662	330	430	490	Do.
Bean Shoal (head)	164.7	1,521	39.17	[b] 4	1,560	2,030	2,320	Rock bottom.
Lime Rock Shoal	169.3	1,165	10.62	[b] 2.59	325	425	490	Do.
Shoal below Rockford.	174.8	1,097	8.38	4,500	240	320	360	Do.
Seven Island Shoal	177.0	1,066	4.02	2,630	112	145	165	Do.
Long Shoal	182.0	949	11.18	[b] 1.61	205	335	385	Do.
Woodruff Fishtrap Shoal.	185.0	925	4.55	1,800	105	134	155	Do.
Mitchell Island Shoal	186.6	925	4.00	2,740	90	115	135	Gravel bottom.
Swan Creek Shoal	196.7	739	5.40	3,160	100	125	145	Rock bottom.
Reeve Island Shoal	206.5	540	3.86	2,700	50	65	75	Rock and gravel bottom.
Blair Island Shoal	216.5	420	3.44	1,700	36	46	53	Gravel bottom.

[a] From Bull. No. 8, N. C. Geol. Survey. [b] Miles.

It will be seen that the fall is not in the form of direct vertical drops, but in shoals of considerable length. One of the greatest drawbacks to the development of power in a large part of the Yadkin is the lack of proper means of transportation.

TRIBUTARIES OF YADKIN RIVER.

DISCHARGE MEASUREMENTS.

The following measurements were made of the important tributaries of the Yadkin to and including Ararat River, in order downstream:

Discharge measurements of upper tributaries of Yadkin River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1900.				*Feet.*	*Sec.-ft.*
June 20	Elk Creek	One-fourth mile above ford	Cleveland Abbe, jr., and N. C. Curtis.	2.4	119.0
July 13	do	do	do	2.43	61.0
Aug. 6	do	do	do	2.60	37.0
Sept. 26	do	do	do	2.61	30.0
June 21	Stony Creek	Footbridge at Colberts	do	2.65	78.4
July 13	do	do	do	2.70	80.5
Aug. 6	do	do	do		50.0
Sept. 26	do	do	do	2.87	31.10
June 21	Louis Fork of Yadkin River.	Footbridge on Mount Pleasant road.	do	3.10	127.0
July 13	do	do	do	3.23	99.0
Aug. 6	do	do	do	3.30	69.0
Sept. 26	do	do	do	3.33	63.0
June 23	Reddie River	North Wilkesboro	do	24.73	218.1
July 12	do	do	do	25.15	98.1
Aug. 4	do	do	do		93.0
Oct. 1	do	do	do	25.25	60.2
June 23	Mulberry River	Trestle of Greensboro and Wilkesboro division of Southern R. R.	do	21.93	108.4
July 3	do	do	do	22.25	50.3
Aug. 4	do	do	do	22.50	39.25
Sept. 27	do	do	do	22.42	61.2
Nov. 2	do	do	do		55.0
June 25	Roaring River	Greensboro and Wilkesboro R. R. bridge.	do	23.68	520.2
July 9	do	do	do	25.45	161.4
Aug. 4	do	do	do	25.75	117.0
Sept. 27	do	do	do	25.13	109.0
Nov. 2	do	do	do	24.27	197.0
Sept. 27	Big Bugaboo Creek	Ford of road from Roaring River to Elkin.	do	1.28	30.0
June 25	Big Elkin River	Greensboro and Wilkesboro R. R. bridge.	do	24.53	65.0
July 9	do	do	do	25.95	29.0
Aug. 4	do	do	do		24.0
Sept. 27	do	do	do	26.22	27.0
June 26	Mitchell River	do	do	21.63	393.1
July 10	do	do	do	24.00	139.2
Aug. 3	do	do	do	24.25	119.0
Sept. 28	do	do	do	24.25	160.0
Nov. 1	do	do	do	23.89	216.0
June 26	Fisher River	Greensboro and Wilkesboro R. R. trestle.	do	20.93	549.0
July 10	do	do	do	23.38	172.0
Aug. 3	do	do	do	23.60	126.0
Sept. 28	do	do	do	23.72	119.0
Nov. 1	do	do	do	23.70	235.0
June 27	Ararat River	do	do	23.9	801.0
July 11	do	do	do	26.0	317.1
Aug. 2	do	do	do	26.25	265.44
Sept. 29	do	do	do	26.46	243.0
Oct. 31	do	do	do	25.66	307.0

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

The drainage basins and water powers of the principal tributary streams are briefly described on the following pages. Practically all of the tributaries whose water powers are worth considering flow into the Yadkin from the north. The divides and spurs, between which are the basins of the tributary streams, are seldom more than a mile wide and form many picturesque coves and valleys.

ELK CREEK.

This stream was measured at a foot log about one-fourth of a mile above the road ford at Elkville. At the point of measurement and for a short distance above and below are cascades over broad ledges of gneiss, and the stream is bounded by steep, rocky slopes. The natural fall is estimated to be at least 10 feet within 200 yards. Higher up the stream there are undoubtedly other fair powers, but they were not examined.

STONY CREEK.

This stream enters the Yadkin from the north about 6 miles below Elkville, and possesses a splendid power at its mouth and for a short distance upstream. Throughout the last half mile of its course the banks are the steep, rocky sides of a narrow, V-shaped gorge. Within this distance the stream has an estimated fall of at least 50 feet, flowing over a series of ledges in falls or cascades of from 6 to 10 feet each. Just at the mouth of the creek there stands a combined sawmill and gristmill driven by turbine power. The dam is only 6 feet high, but is so favorably placed on ledges that about 18 feet head is obtained. This is an excellent mill site, but the road leading down to it from the surrounding country is poor and is on a steep grade. The stream was measured at a foot log about 3 miles above its mouth, where it flows through a sandy meadow or bottom one-fourth of a mile wide. So far as examined this stream offers a number of good mill sites, for its valley is everywhere bounded by steep mountain sides, and in many places is narrow, by reason of the occurrence of bands of resistant gneiss and schist.

LOUIS FORK.

This stream has a large drainage basin, served by its two branches, East Fork and West (or South) Fork. The valleys of these branches are generally open and are largely cleared, the bottom lands, of which there is a large area, being under cultivation. The discharge was measured (see table on page 164) at a foot log where the Mount Pleasant road crosses the stream, just below the confluence of the East and West forks. The bottom at this place is rather sandy and gravelly, with some large bowlders. About one-fourth of a mile downstream, however, the creek leaves the meadows and enters a narrow,

steep-sided gorge containing many rocky ledges. There are one or two small gristmills on the forks above the point of measurement, which is nearly 3 miles from the mouth, but so far as known there are none below it.

UNNAMED TRIBUTARY EAST OF LOUIS FORK.

There is a small stream which heads in the mountains northeast of Purlear and enters the Yadkin from the north about a mile west of Brown's ford, on which there is considerable fall, over rock ledges, at the mouth. This fall is utilized by a gristmill and yields a head of 10 feet, although the dam is only 5 feet high. The stream is so small that it was not possible to measure its discharge satisfactorily with the large meter. Judging from the wooded character of its valley, however, it has a fairly uniform flow throughout the year, and its steep grade gives much more power than is now used.

REDDIE RIVER.

This river heads far up among spurs of the Blue Ridge, between Horse Gap on the west and Mulberry Gap on the east. Its headwaters are moderately well wooded, but along its middle course there is more open and cleared valley land. There are several mills on the stream, the more important ones being a gristmill at Whittington and two mills at its mouth, just above North Wilkesboro. The latter mill site is an admirable one, the shoal being 10 or 15 rods wide, rock-floored, and excellent rock abutments being furnished by the ledges on either bank. The natural fall in the channel is about 10 feet, half of which is utilized, by means of a 9-foot dam, by a gristmill and flour mill on the west bank. One hundred yards below the dam a sash factory uses a fall of about 14 feet, obtained by sluicing the water from the dam to the east bank of the stream.

The river is reported to be not subject to rapid fluctuation, thus distinguishing it from most of the other streams of the neighborhood.

MULBERRY RIVER.

This river also rises far back in the Blue Ridge, starting near Mulberry Gap and flowing southeastward. Its valley, which is rather broad, is covered with alluvium and offers relatively few mill sites. The average grade of the channel seems to be much less than that of most of the streams of the district. In the upper stretches falls and rapids are more numerous than in the lower portions of its course. About halfway between Mulberry and Halls Mills there is a shoal which affords fall for Wood's gristmill and sawmill, giving the wheel 8 feet head. So far as known this is the only mill on the stream. At the crossing of the road between North Wilkesboro and the town of Roaring River there is an excellent little fall of about 6 feet, due to

a broad ledge of rock which crosses the stream and furnishes a good abutment on the west bank. At the Southern Railway trestle there is also a series of cascades furnishing 6 feet fall, with good abutments on the east bank. The river was measured at the trestle, which is about halfway between the Yadkin and the steep hillside forming the northern boundary of that river's flood plain.

ROARING RIVER.

This stream is much larger than Mulberry River and possesses many good water powers. Those at present best known are the one about 4 miles below Dockery, which is near the junction of the eastern and western forks, and the one at the mouth of the stream.

Just above the confluence of the two chief forks a small stream enters the western fork from the southwest. Where the road from Round Mountain to Dockery crosses it the average fall is 100 feet per mile. Here Spencer Blackburn has built a small mill which uses a fall of 20 feet. Passing on to the two forks and to the main stream below the ford of the eastern road from Round Mountain to Dockery, the river is very rapid and is confined between high and steep banks. Its fall averages 20 feet to the mile, and the shoals, including the Big Shoals, cover a distance of about 1 mile. All of this fall can be made to furnish excellent power, both on the main stream and on the northern fork, which joins the river at this point, after draining a region to the northeast lying between Hank Store and Lomax.

Though narrow and steep sided in the vicinity of the Big Shoals, the valley widens a short distance below, and the stream possesses no valuable powers until about one-fourth mile above the railway trestle at its mouth, where a series of cascades over firm rock ledges causes the channel to drop 15 feet within half as many rods. At the trestle the valley opens out into the sandy flood plain of the Yadkin.

BIG ELKIN RIVER.

This stream has three noteworthy falls, which give it an important place among the water powers of the upper Yadkin Valley. The most important falls, or series of falls, so far as water power is concerned, are Carters Falls, about 3 miles above the mouth of the stream, at a place known as Cool Spring Church. When visited during the summer of 1900 these falls had a comparatively small volume of water. They are occasioned by a broad band of resistant hornblende-gneiss. The upper fall, which is the greater, was measured by a hand level and found to be 60 feet in a distance of 100 yards. From the foot of this fall the stream runs over low ledges for an eighth of a mile to a lower fall which is about 15 feet high. The latter fall is utilized by a small turbine-driven gristmill on one bank and by a small lumber mill on the other bank. The owner of

the land states that he has measured the total fall here, from the head of the upper to the foot of the lower falls, by means of accurate instruments, and finds it to be 92 feet, which seems quite possible. The banks of the gorge are steep and of firm rock, affording the finest water-power site between Ararat River and the source of the Yadkin.

About a half mile below the lower falls mentioned there is a fall of about 25 feet, part of which has been utilized by Butler's gristmill, which has a dam 6 feet high yielding 14 feet head. By extending the race a few yards farther downstream a head of 20 feet could be obtained. During high water there is a maximum rise of 3 feet above the top of the dam.

The other powers are near the mouth of the river, in the towns of Elkin and Elkin Valley. At the former place, where there is a favorable rock bottom and decided falls, are two dams; at the latter place, which is higher upstream, there is a gristmill and flour mill with a 10-foot dam and a fall of 18 feet.

MITCHELL RIVER.

This stream was measured just below a series of low rapids over rocky ledges, marking the point of transition from the rocky channel of back country to the sandy flood plain of the Yadkin. The fall, about 10 feet, has not been utilized though it is favorably situated. About 1 mile upstream Burch's flour mill obtains power from a tributary—Snow Creek. At Guyer Ford, 6 miles above the mouth, there is a broad shoal which would give 5 to 7 feet fall within a quarter of a mile.

The valley of Mitchell River is similar to that of Fisher River, being rather narrow, with steep side slopes, but it has been somewhat more cleared than the latter valley. Perhaps half the area of the immediate slopes is now bare of trees, while in the valley of Fisher River two-thirds of the timber seems to be standing.

FISHER RIVER.

This stream was ascended only a short distance. No improved mill sites were found, though a number of small mills are reported along its upper course. Many mills, however, are located on small tributaries of the river. The stream is a large one, being 30 to 40 miles long, rising far back upon the Blue Ridge, in about the same latitude as Mount Airy. Probably the only good mill site is at the neck of what is known locally as The Oxbow or The Horseshoe, a semicircular bend in the river about 5 miles southeast of Dobson. The two arms of this loop come within 100 yards of each other at the narrow neck, and there is said to be a difference of 20 feet in the surface level of the river on the two sides. It has been suggested that this difference in level be utilized by piercing the neck with a tun-

neled race, but nothing in that direction has yet been done. At the ford of the road between Snow's mill and Butcher there are shoals due to a fall of perhaps 5 feet in one-fourth of a mile, and at the ford southwest of Butcher there is a long shoal giving 4 or 5 feet fall in 200 yards. The valley appears too wide for dam construction, but just below the second shoal mentioned it narrows and closes in for a short distance.

ARARAT RIVER.

Ararat River is the largest of the upper tributaries of the Yadkin. It rises on the Blue Ridge, about 10 miles north of Mount Airy, at an elevation of 2,500 feet, and flows almost due south for 30 miles, emptying into the Yadkin 1 mile below Siloam. The average fall per mile from the mouth to Mount Airy, a distance of 20 miles, is 14.6 feet. Above Mount Airy, where the fall is much greater, there are a number of small gristmills.

NEW RIVER.

New River rises in Watauga County, N. C., and flows in a general northeasterly direction through Watauga and Ashe counties. It then follows the North Carolina–Virginia State line for about 12 miles, when it turns to the north and joins Kanawha River, its waters finally reaching the Ohio. Just before it intersects the North Carolina-Virginia boundary line there is a confluence of two branches of almost equal size, known as the South Fork and the North Fork. The North Fork drains the eastern slopes of the Iron Mountains along the southwestern border of Ashe County, N. C. Both forks are formed by the junction of several branches which drain the mountain slopes. The total drainage area of the two forks is 631 square miles.

Examination of the drainage basin of the river was made as far down as Oldtown, in Grayson County, Va., about 7 miles below the confluence of the North and South forks. The upper part of the basin is rough and mountainous, the stream flowing through gorges and narrow valleys with rocky slopes and bottoms. The occasional widening of the valleys, however, furnishes favorable sites for dams and mills. The soil is for the most part deep and fertile, making a fine agricultural region. According to the census of 1880, 92,000 acres were under cultivation, 57,000 acres were in grass, and 240,000 acres, or 61 per cent of the whole, were in original timber. The annual rainfall in the basin, as indicated by a single station, viz, Blowing Rock, is about 49 inches, distributed as follows: Spring, 11.3 inches; summer, 16.2 inches; autumn, 9.7 inches; and winter, 11.8 inches. The region is rich in mineral resources, especially in iron and copper, though very little has been done in the way of development.

The total length of the river between the junction of the forks and Oldtown, Va., is about 35 miles, and the average fall per mile about

8.5 feet. The river winds its way in narrow gorges formed by the shutting in of the hills on either bank. Bottom land is therefore scarce. The section of Virginia through which this portion of the river flows is chiefly devoted to stock raising. The land is fertile and the soil deep and of a reddish color. The region is well settled, the people thrifty, and large and well-cultivated farms can be seen everywhere. Wheat and other grains are the chief crops.

During the investigation a gaging station was established (July 31, 1900) near Oldtown, Va., and two measurements were made there (see table below). Measurements were also made of tributaries of the river between the confluence of the North and South forks and Oldtown, as shown in the following table. The basins of the North and South forks are described under separate headings, and the measurements made on those streams and their tributaries are given in the tables on pages 172 and 174.

Discharge measurements of New River near Oldtown, Va., and of its tributaries between confluence of North and South forks and Oldtown.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge
				Feet.	*Sec.-ft.*
1900. July 28	Wilson Creek	2 miles above mouth	Cleveland Abbe, jr., and N. C. Curtis.	6.3	35.1
Oct. 28	do	do	do	6.1	78.0
July 29	Fox Creek	One-fourth mile above mouth	do		85.0
Oct. 28	do	do	do		144.0
1901. June 28	do	do	do		352.0
1900. July 31	Peach Bottom Creek	200 yards above mouth	do	4.9	21.4
Oct. 29	do	do	do		36.0
July 31	Little River	Ford of Independence-Oldtown road.	do	9.1	199.0
Oct. 29	do	do	do		318.2
July 30	Elk Creek	200 yards above mouth	do	4.0	57.1
July 31	New River	Near Oldtown	do	6.6	1,541.0
Oct. 29	do	do	do	6.3	2,293.0

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in the gage height represents an increase in the discharge of the stream.

The water powers of all of the streams mentioned in the foregoing table are excellent, and many of them have already been developed. At the mouth of Wilson Creek there are two mills—the lower one a grain mill with a fall of 12 feet, and the upper one a woolen factory, owned by Fields & Hash. On Peach Bottom Creek, 2 miles east of Independence, is the gristmill of D. C. Mallory. The total fall here is about 65 feet.

SOUTH FORK OF NEW RIVER.

GENERAL FEATURES.

This stream is formed by the confluence of the East Fork, the Middle Fork, and Flannery Fork, near Deckhill, Watauga County, N. C. The Middle Fork, which is the largest of the three tributaries mentioned, rises just north of Blowing Rock, at the boundary line between Watauga and Caldwell counties, at an elevation of between 3,700 and 3,800 feet. The elevation at the junction of the North and South forks being 2,500 feet, the difference in elevation between the head and the mouth of the South Fork is 1,300 feet, the distance 45 miles. This gives an average fall of 29 feet to the mile. As the course of the stream, however, is extremely crooked the slope is hardly 20 feet to the mile. Shoals and available water powers are not numerous on the main stream, but on the branch streams they are more frequent and have been more extensively utilized.

The area drained by the South Fork presents a very great diversity of scenic features. The general course of the stream is parallel to the Blue Ridge. On the north are very high knobs and ridges. The highest of these is Snake Mountain, 5,594 feet high. The scenery presented though not rugged is extremely beautiful. The basin of the river is for the most part closed, and there are no extensive bottom lands.

The proportion of unimproved cleared land in Watauga and Ashe counties is small compared with the agricultural lands. On many of the mountains the timber is practically untouched. The trees, however, are not of the most valuable varieties. They are chiefly maples and chestnuts. The larger portions of the cleared land are devoted to the production of grass and hay, and consequently the raising of cattle and sheep is a most important industry. The chief crops are corn, wheat, buckwheat, and cabbages, to all of which the soil is especially well adapted. Large quantities of apples are also produced. The people are well to do and prosperous. The region is very healthful; typhoid and malarial fevers are unknown.

No railroad has yet penetrated Watauga County, though a route has recently been surveyed and a tax voted. The route surveyed crosses the Blue Ridge at Cook Gap. The country roads are for the most part good and are being improved and kept open for travel. The turnpike between Boone and Blowing Rock is remarkably well graded, and it is possible for loaded wagons to cross the Blue Ridge to Lenoir throughout the year. Lenoir is at present the shipping point for the produce of the county. The people of Ashe County are not so progressive in the matter of road building as are the people of Watauga County.

Both the North Fork and the South Fork are at times swollen by heavy freshets, which are often very destructive to crops on the bottom lands. Occasionally the soil is entirely removed from the bottoms and the bed rock exposed. More often, however, where the current is not very swift, a rich coating of black mud from one-half inch to 4 inches thick is deposited, enriching the lowlands considerably.

DISCHARGE MEASUREMENTS IN BASIN.

During the investigation a gaging station was established on the South Fork at New River, N. C. The measurements made there, as well as those made at Riverside, also the measurements made on the tributaries, are given in the following table, in order downstream:

Discharge measurements of South Fork of New River and its tributaries.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
1900. July 28	South Fork of New River	New River	Cleveland Abbe, jr., and N. C. Curtis.	2.70	751.0
Oct. 28	do	do	do	2.60	1,635.0
1901. June 27	do	do	do	3.90	1,976.0
1900. July 18	do	Riverside	do	11.85	165.0
Oct. 25	do	do	do	11.00	741.1
1901. June 24	do	do	do		968.0
Do	do	Ford near mouth of Middle Fork of New River, near Boone.	do	7.10	159.0
Do	West Fork	Near Boone	do	5.40	108.0
1900. July 23	Flannery Fork	Ford of Boone-Blowing Rock road.	do	6.35	10.4
Oct. 24	do	do	do	5.35	107.0
July 23	Middle Fork	Ford of Boone-Aho road	do	5.70	24.4
Oct. 24	do	do	do		234.0
July 23	East Fork	do	do	5.70	10.4
Oct. 24	do	do	do	5.10	109.0
July 18	Meat Camp Creek	One-fourth mile below Moretz.	do	9.00	35.3
Oct. 25	do	do	do	8.65	89.0
1901. June 24	do	do	do	7.90	164.0
1900. July 24	Elk Creek	Elk Crossroads	do	8.00	10.0
July 18	Old Field Creek		do	6.1	19.4
July 24	Gap Creek	One-eighth mile above mouth	do	4.85	23.4
July 19	Beaver Creek	At mouth	do	6.00	22.4
July 27	Mulberry Creek	Near mouth	do	5.1	109.0
Do	Prather Creek	One and one-half miles below Scottville.	do	8.6	25.0

NOTE.—In making the measurements recorded in the above table bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in gage height represents an increase in the discharge of the stream.

WATER POWERS IN BASIN.

There are a number of undeveloped water powers on the South Fork and its tributaries, the chief of which are the following:

On the Middle Fork, about 5 miles from Blowing Rock, there is a fall of possibly 15 feet in 100 feet, with a good dam site, though the space for building purposes is somewhat cramped. On Meat Camp Creek, at Moretz, there is a mill with a dam about 8 feet high. On Elk Creek, at Elk Crossroads, there is a small sawmill. The discharge of this stream is slight, but a fall of about 20 feet has been obtained. On Beaver Creek, at the town of Beavercreek, is Hamilton's corn and flour mill, with a working head of about 10 feet.

Near the mouth of the South Fork are the remains of an old dam. The site is a good one, a rock ledge running entirely across the stream and high hills shutting in close on both banks. A dam 40 feet in height could easily be constructed here. Near Scottville the river makes an almost closed loop, and it has been proposed to tunnel through the neck of the loop and in that way develop a fall. It is said that the difference in the elevation of the surface of the water on the upper and lower sides of the loop is about 30 feet.

Owing to the steep slopes of the adjacent mountains the river and its tributaries are subject to floods, and dams and buildings for the development of the water powers would have to be built strong and substantial.

NORTH FORK OF NEW RIVER.

GENERAL FEATURES.

The North Fork is formed by the junction of Hoskin Fork and Brush Fork in the extreme southwestern part of Ashe County.

The character of the region through which it flows is more mountainous than the basin of the South Fork; the same general agricultural and forest conditions prevail here as in the latter basin. The stream is not so tortuous as the South Fork, but its side streams are more numerous and the fall greater. Its total length is about 30 miles. The difference in elevation between its head and the junction with the South Fork at Weaversford is 1,800 feet, making the average fall per mile 60 feet.

Its main upper branch, Hoskin Fork, rises on the eastern slope of Snake Mountain, at an elevation of 4,300 feet. It flows between closed hills, and its flood plain is very narrow.

The ratio of cleared to forest-covered land in the watershed is estimated to be about 1 to 5. The region about the headwaters is very thinly settled. The scenery is magnificent, especially near Creston and Solitude. The cleared land is chiefly devoted to cattle grazing.

DISCHARGE MEASUREMENTS IN BASIN.

On July 27, 1900, a gaging station was established on the North Fork at Weaversford, N. C. The measurements made there, as well as those made at other points along the river, also the measurements made on its tributaries, are given in the following table, in order downstream:

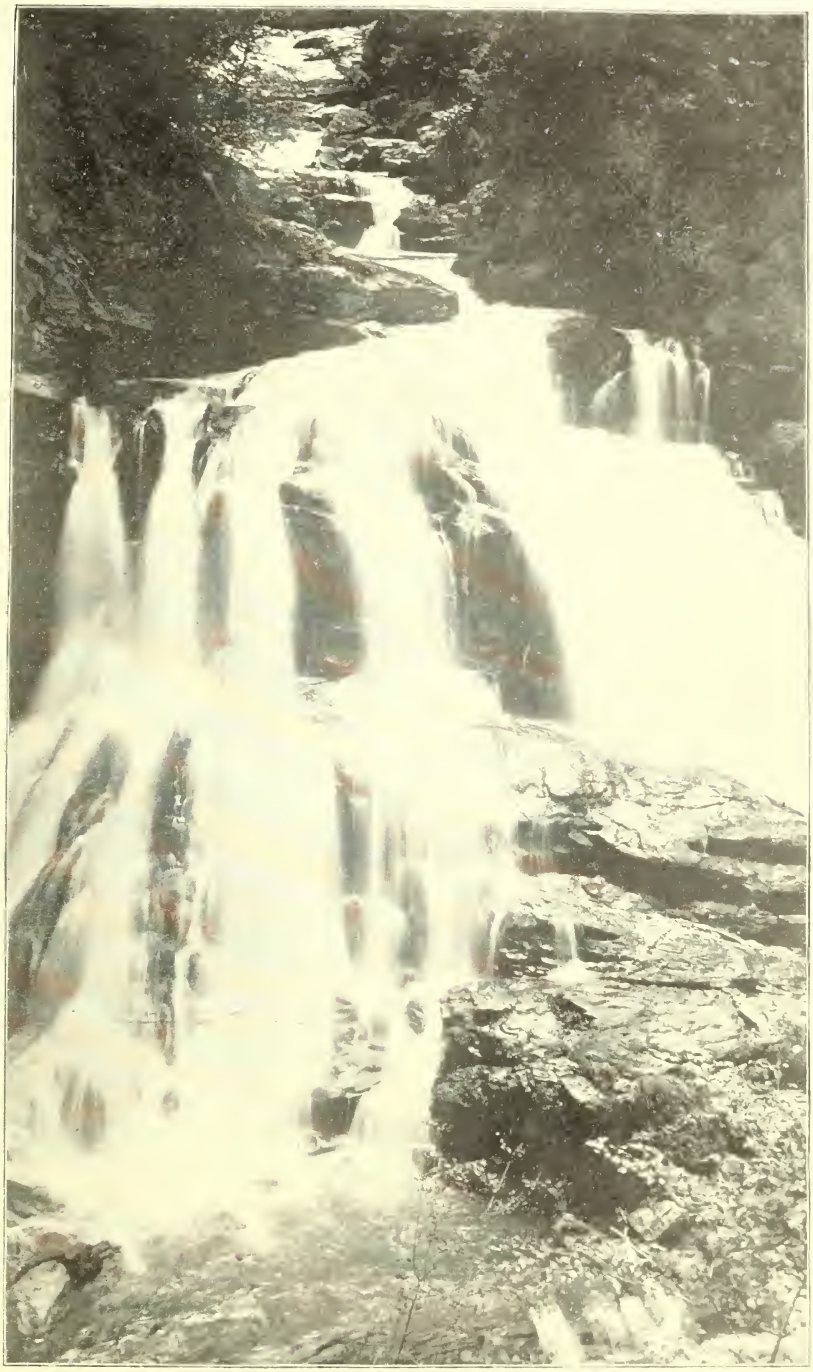
Discharge measurements of North Fork of New River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
				Feet.	*Sec.-ft.*
1900. July 28	North Fork of New River.	Weaversford	Cleveland Abbe, jr., and N. C. Curtis.	0.60	536.0
Oct. 27	do	do	do	0.90	708.0
1901. June 27	do	do	do	1.40	1,377.0
June 20	do	Below mouth of Laurel Creek	do	1.00	313.0
1900. July 21	do	1 mile below Creston	do	6.7	49.3
Oct. 26	do	do	do	6.0	194.0
1901. June 20	do	do	do	5.5	196.0
1900. July 20	do	½ mile from Creston, on road to Solitude.	do	2.65	32.2
Do	Threetop Creek	Creston	do	6.75	130.0
July 21	do	do	do	7.25	37.0
July 20	Big Laurel Creek	100 yards above mouth	do	6.40	26.2
Oct 26	do	do	do	6.30	80.4
July 20	Buffalo Creek	⅛ mile above mouth	do	5.43	44.0
Oct. 26	do	do	do		67.0
1901. June 20	do	Near Jefferson	do	4.30	140.0
1900. July 25	Horse Creek	¼ mile above mouth	do	6.6	34.3
Oct. 27	do	do	do	6.05	140.0
1901. June 25	do	do	do	5.35	444.0
1900. July 25	Helton Creek	Below Peasley's mill	do	4.28	30.0
Oct. 27	do	do	do		105.0

NOTE.—At regular stations of the Geological Survey gages are installed by which the rise of the river is measured, an increase in the gage height representing an increase in the discharge of the stream. This is true of the measurements in the above table made at Weaversford. In making all of the other measurements, however, in each case a bench mark was established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. In the latter cases, therefore, an increase in the gage height means a lowering of the water surface and a corresponding decrease in the discharge of the stream.

WATER POWERS IN BASIN.

There are a number of water powers in the basin. Those of Threetop Creek are very good. Four mills were observed, with falls ranging from 6 to 15 feet. Shoals and dam sites are numerous. At the falls of Long Hope Creek, a branch of Threetop Creek, there is a total fall of 300 feet in 400 yards. The average discharge of Long Hope Creek is about 10 second-feet. On the North Fork about 3 miles west of the mouth of Buffalo Creek, near Dresden, there is an important water power which at one time was utilized, but the dam was destroyed by a freshet and has not been rebuilt. The hillsides at this point shut



LOWER FALLS OF CULLASAGEE CREEK, NORTH CAROLINA A TRIBUTARY OF LITTLE TENNESSEE RIVER.

OCONALUFTY VALLEY NORTH CAROLINA.

in close, and a rock ledge extends across the stream. A fall of 30 or 40 feet could readily be obtained. Horse Creek and Helton Creek are both large streams with considerable fall. No water powers were observed on the former. A combined sawmill and gristmill is located about a half mile above the mouth of Helton Creek. The fall obtained is about 10 feet and the power is developed by turbines. This is also the site of the old Helton iron works, where hammered iron was formerly worked, the ore being obtained in the vicinity. On the North Fork about 2 miles from its mouth is Dixon's corn and flour mill. A dam about 8 feet in height has been constructed here. The flume leading to the forebay is a tunnel cut through a projecting shelf of rock, behind which is a mill house. A masonry dam 40 feet high could be constructed and the power greatly increased.

STREAMS SOUTHWEST OF FRENCH BROAD RIVER.

South and west of the region already described is a large, mountainous area with many of the same characteristics. From this territory flow the headwaters of four of the largest rivers in the Southeastern States. First comes the Tennessee River, the basins of several of the largest branches of which, namely, the Holston, the Watauga, the Nolichucky, and the French Broad, have been described in detail in this paper. Farther south are the Oconaluftу, the Tuckasegee, the Nantahala, the Hiwassee, the Okoee, and other rivers which enter the Tennessee and after a long and winding course add their waters to the Mississippi. (Typical views of these streams are shown in Pls. XXXIX to XLIV.) The second large river is the Savannah, which receives numerous tributaries and flows in a southeasterly direction into the Atlantic. The third stream is the Apalachicola River, which with its chief tributary, the Chattahoochee, rises close to the headwaters of the Tennessee and after a southerly course between Georgia and Alabama and through Florida enters the Gulf of Mexico at Apalachicola. The fourth large stream is the Mobile, which receives its headwaters from the mountains of Tennessee and northern Georgia, through the Coosa, the Conasauga, and the Etowah, and flowing through the State of Alabama enters the Gulf at Mobile.

Hydrographic studies and numerous measurements of discharge, in charge of Prof. B. M. Hall, have been made by the United States Geological Survey of the headwaters of all of these streams and of their chief tributaries. Most of the streams rise on the steep slopes of the mountain sides, at elevations of from 2,000 to 4,000 feet above sea level, and have large falls throughout their courses. In many places the streams flow through mountain gorges with steep, vertical sides and with very small flood plains.

Only a small proportion of the region is under cultivation, the greater part being still covered with the original forest growth, consisting of oak, hickory, chestnut, poplar, locust, pine, buckeye, linn, ash, maple, sassafras, walnut, and other varieties. The ground is

frequently covered with trailing arbutus, maidenhair and other ferns, deep-green mosses, and a great variety of wild flowers and rare medicinal plants. The climate is mild throughout the year, making it a fine resort in winter as well as in summer. Wild animals, such as deer, bears, and wolves, once so numerous, are now nearly extinct, but there are still many wild-cats, catamounts, minks, foxes, opossums, ground hogs, polecats, weasels, wild turkeys, pheasants, squirrels, rabbits, quails, etc. The land now under cultivation is practically all that is available for ordinary farming, the remainder being steep, rocky, and rugged, with only occasional patches of deep, fertile soil. Near the rivers considerable timber has been cut, but the lumbering has not extended far up the mountain sides. Means of transportation are exceedingly meager, the Murphy branch of the Atlanta, Knoxville and Northern Railway being about the only outlet. For this reason the few farming products that are raised can not be transported economically to the populated districts, so that there is little incentive to agricultural pursuits. The greater portion of the grain raised is made into moonshine whisky, and the summer apples are largely used for apple-jack. Wheat, cabbages, Irish potatoes, and the hardier fruits grow well.

The mineral resources are practically untouched and comparatively unknown, but they are evidently important and varied. Gold, corundum, asbestos, marble, talc, kaolin, ocher, iron, and mica are known to exist. The whole region is sparsely inhabited. Water powers are very numerous, though few are developed, and most of these on only a small scale, for gristmills and sawmills. The large undeveloped powers on the lower parts of the streams are well distributed and are very valuable for manufacturing purposes. After the rivers leave the mountain region and flow across the broad, elevated plains, large falls frequently occur, some of which have in recent years been developed and have proved to be most lucrative investments.

The results of the measurements upon the streams in this region are given in the following tables, arranged in chronologic order:[a]

Discharge measurements of tributaries of Tennessee River north of Hiwassee River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1901.				*Feet.*	*Sec.-ft.*
Feb. 18	Conasauga Creek	Near Cambria, Tenn	B. M. Hall and assistants.		101
Feb. 19	Tellico River	1½ miles above mouth	do		316
Do	Little Tennessee River.	½ mile below mouth of Tellico River.	do	3.10	4,774
Feb. 20	Little River	1 mile above mouth	do		374
Feb. 21	West Fork of Little Pigeon River.	At bridge just above mouth	do		133

[a] In making the measurements recorded in these tables bench marks were established and measurements were made, by means of a steel tape, of the distance from the bench mark to the surface of the water. An increase in the gage height, therefore, means a lowering of the water surface and a corresponding decrease in the discharge of the stream, the reverse of the results at the regular stations of the Survey, where gages are installed and where an increase in gage height represents an increase in the discharge of the stream.

TUCKASEGEE RIVER NEAR DILLSBORO, N. C.

TUCKASEGEE FALLS, NORTH CAROLINA.

Discharge measurements of tributaries of Tennessee River north of Hiwassee River—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1901.				*Feet.*	*Sec.-ft.*
Feb. 21	Little Pigeon River	At bridge just above junction with West Fork of Little Pigeon.	B. M. Hall and assistants.		167
Feb. 22	East Fork of Little Pigeon River.	Near mouth	do		[a]30
Do	Cosby Creek	At mouth	do		60
Feb. 23	Big Pigeon River	At bridge above mouth of Cosby Creek.	do		778
Apr. 3	Tellico River	At bridge 1½ miles above mouth.	do		2,580
Do	Little Tennessee River.	McGhee, Tenn	do		30,536
Apr. 4	Little River	Halfway between Louisville and Knoxville, Tenn., at A., K. and N. Ry. bridge.	do		2,012
Sept. 11	Collins River	McMinnville, Tenn	do	2.60	310
Nov. 4	Little Tennessee River.	McGhee, Tenn	do	2.50	2,675
Do	Tellico River	At bridge 1½ miles above mouth.	do		180

[a] Estimated.

Discharge measurements of Hiwassee River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1901.				*Feet.*	*Sec.-ft.*
Jan. 10	Stanley Creek	1 mile above mouth	B. M. Hall and assistants.		49.0
Do	Big Creek	Near mouth	do		86.0
Jan. 11	Noontootly Creek	At foot log ½ mile from mouth.	do		207.0
Do	Toccoa River	At Van Sant's bridge	do	5.05	2,475.0
Do	Skeenah Creek	1 mile above mouth	do		109.0
Jan. 12	Rock Creek	Near mouth	do		132.0
Do	Cooper Creek	Bridge 1 mile above mouth	do		387.0
Do	Toccoa River	1½ miles above mouth of Cooper Creek.	do		396.0
Do	Mill Creek	At mouth	do		122.0
Do	Toccoa River	Just above mouth of Mill Creek.	do		43.0
Jan. 14	Suches Creek	Near mouth	do		61.0
Do	Toccoa River	Just below Suches Creek	do		175.0
Do	Coosa Creek	Bridge about 2½ miles from mouth.	do		75.0
Do	Nottely River	Bridge 1½ miles from Blairsville, Ga.	do	1.45	450.0
Do	Butternut Creek	Just below bridge at mouth	do		32.0
Jan. 15	Arququah Creek	At Choestoe road	do		40.0
Do	Town Creek	½ mile from mouth	do		85.0
Do	Stink Creek	1 mile above mouth	do		48.0
Do	Nottely River	At foot log just above mouth of Stink Creek.	do		131.0
Do	Wolf Creek	On south side of Nottely River	do		55.0
Jan. 16	Young Cone Creek	1 mile above mouth	do		94.0
Do	Ivy Log Creek	½ mile above mouth	do		33.9
Jan. 17	Nottely River	At Thompson's bridge at Ivy Log, Ga.	do	1.20	616.0
Jan. 18	Brasstown Creek	At bridge near mouth	do		149.0
Jan. 21	Hiwassee River	Just above mouth of Hightower Creek.	do		152.0
Do	Bell Creek	At mouth	do		24.0
Do	Hightower Creek	Near mouth	do		116.0
Jan. 22	Hiwassee River	Bridge 1½ miles below Hiwassee, Ga.	do		306.0
Jan. 24	Hemptown Creek	Just above mouth of Youngstone Creek.	do		159.0
Do	Hothouse Creek	About 2 miles above mouth	do		75.0
Jan. 25	Greasy Creek	Near mouth	do		88.0
Jan. 26	Okoee River	Parksville, Tenn	do		1,602.0
Aug. 19	Toccoa River	1¼ miles south of Gaddistown, Ga.	do		67.4
Aug. 20	Williams Creek	½ mile south of Gaddistown, Ga.	do		22.8
Do	Nickle Creek	¼ mile south of Gaddistown, Ga.	do		12.8

Discharge measurements of Hiwassee River and tributaries—Continued.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1901.				*Feet.*	*Sec.-ft.*
Aug. 20	Toccoa River	½ mile southeast of Gaddistown, Ga.	B. M. Hall and assistants.		147.6
Do	Suches Creek	1 mile northeast of Gaddistown, Ga.	do		144.0
Do	Cooper Creek	Near fork between Gaddistown and Blairsville, Ga.	do		251.5
Do	Mulky Creek	do	do		75.0
Do	Nottely River	1 mile southwest of Blairsville, Ga.	do		955.0
Aug. 21	Christopher Creek	2½ miles southeast of Blairsville, Ga.	do		39.1
Do	Arququah Creek	3¾ miles southeast of Blairsville, Ga.	do		96.0
Do	Foun Creek	6 miles southeast of Blairsville, Ga.	do		279.0
Do	Stink Creek	Near Choestoe, Ga	do		167.0
Do	Choestoe Creek	5¼ miles southeast of Choestoe, Ga.	do		160.0
Aug. 23	Miller Creek	¼ mile northeast of Blairsville, Ga.	do		87.0
Do	Brasstown Creek	1½ miles southwest of Young Harris, Ga.	do		139.0
Aug. 26	Long Bullet Creek	3 miles northwest of Hiwassee, Ga.	do		[a]26.0
Do	Hog Creek	1½ miles northwest of Hiwassee, Ga.	do		42.0
Do	Hiwassee River	1 mile northwest of Hiwassee, Ga.	do		1,039.0
Do	Fodder Creek	3 miles southeast of Hiwassee, Ga.	do		110.7
Do	Hiwassee River	3 miles north of Mountain Scene, Ga.	do		529.8
Do	Cinth Creek	2 miles north of Mountain Scene, Ga.	do		89.0
Aug. 27	Hiwassee River	¾ mile north of Mountain Scene, Ga.	do		92.0
Do	Owl Creek	1 mile north of Mountain Scene, Ga.	do		87.1
Aug. 21	Fightingtown Creek	8 miles from mouth	do		236.0
Aug. 22	Weaver Creek	2 miles from mouth	do		97.0

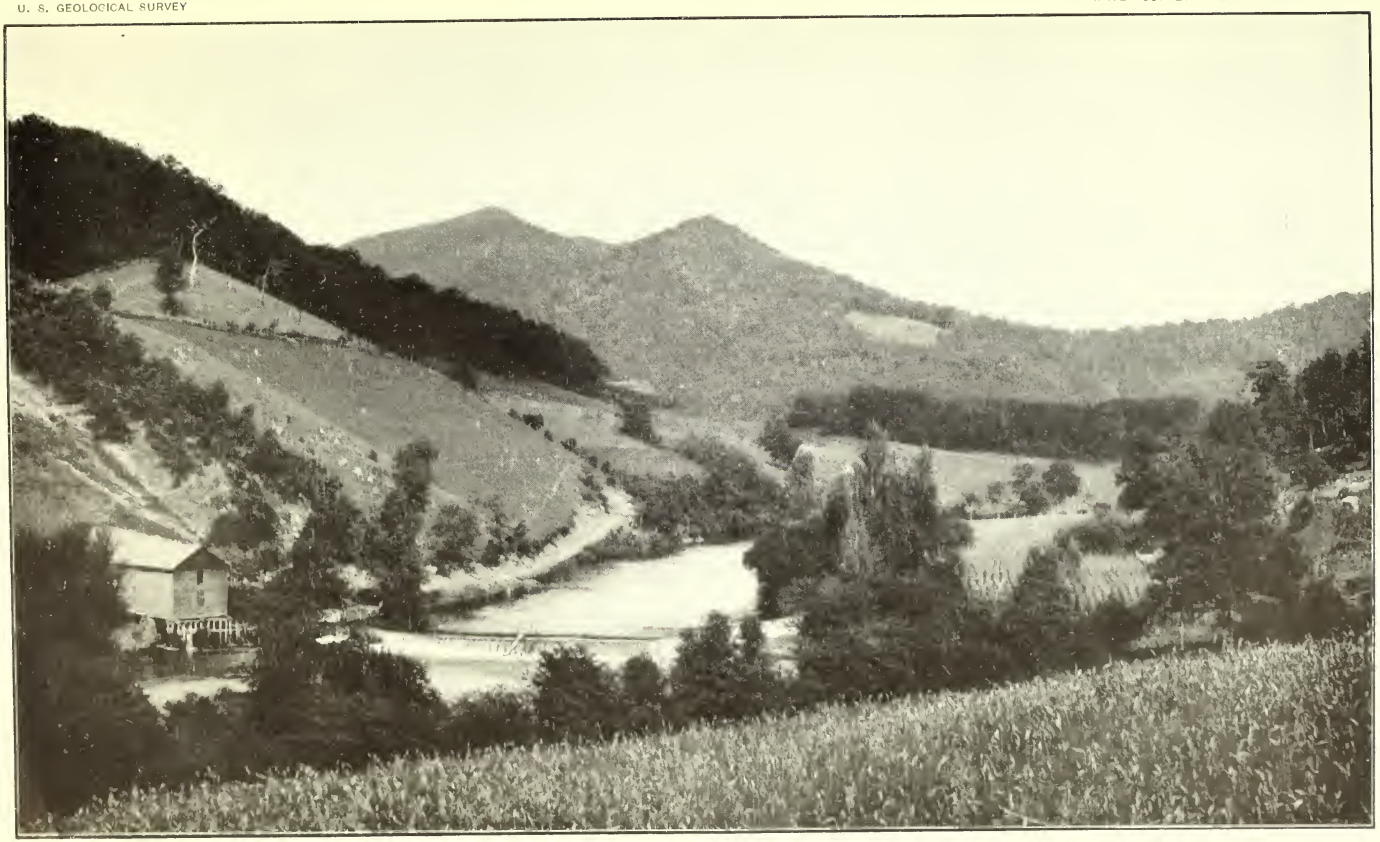
[a] Estimated.

Discharge measurements of Duck and Elk rivers, Tennessee.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Feb. 9	Duck River	Columbia, Tenn	Max Hall	2,418
Do	Elk River	Fayetteville, Tenn	do	1,828
Apr. 19	Duck River	Columbia, Tenn	do	9,504

Discharge measurements of tributaries of Savannah River.

Date.	Stream.	Locality.	Hydrographer.	Gage height.	Discharge.
1901.				*Feet.*	*Sec.-ft.*
Apr. 24	Rocky River	5½ miles northwest of Calhoun Falls, S. C.	B. M. Hall and assistants.		546.0
Aug. 12	do	do	do		448.0
Aug. 13	Little River	5 miles west of Calhoun Falls, S. C.	do	1.35	107.0
Sept. 30	Stekoa Creek	2 miles south of Clayton, Ga	do		71.0
Do	Mill Creek	do	do		7.9
Oct. 19	Tiger Creek	Tallulah Falls, Ga., ½ mile above mouth.	do		151.0



WATER-POWER DEVELOPMENT ON TUCKASEGEE RIVER NEAR PAINTER, N. C.

OKOEE RIVER NEAR DUCKTOWN, TENN.

Discharge measurements of Flint River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Mar. 9	Kinchafoonee Creek	Albany, Ga	B. M. Hall	1,208
Do	Muckalee Creek	1⅝ miles above mouth	do	1,777
Do	Blue Spring Creek	4 miles below Albany, Ga	do	95
Mar. 26	Kinchafoonee Creek	Albany, Ga	F. A. Murray	1,920
Do	Muckalee Creek	do	do	3,244
Apr. 17	Flint River	1 mile south of Montezuma, Ga	do	5,099
Apr. 18	Kinchafoonee Creek	Albany, Ga	do	1,741
Do	Muckalee Creek	do	do	2,600
July 18	Flint River	1½ miles east of Montezuma, Ga	do	2,398
July 19	Kinchafoonee Creek	Near Albany, Ga	do	714
Do	Muckalee Creek	do	do	1,001

Discharge measurements of Chattahoochee River and tributaries in Georgia.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Jan. 7	Nancys Creek	7 miles northeast of Atlanta, on Peachtree road.	J. C. Conn	45.9
May 15	Sweetwater Creek	Austell, Ga	K. T. Thomas	188.0
June 25	Chattahoochee River	3½ miles northwest of Gainesville, Ga.	F. A. Murray	1,306.0
Oct. 24	Baldridge Creek	Near Buford, Ga	Max Hall	23.5

Discharge measurements of Chattahoochee River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Jan. 12	Yahoola ditch	1 mile east of Dahlonega, Ga	B. M. Hall and assistants.	39.5
Do	Yahoola Creek	2 miles east of Dahlonega, Ga	do	309.2
Do	Chestatee River	5 miles east of Dahlonega, Ga	do	1,477.1
Jan. 13	East Fork of Tessantee Creek.	3 miles northeast of Cleveland, Ga	do	10.3
Do	Dukes Creek	1½ miles southwest of Nacoochee, Ga	do	265.2
Do	Chattahoochee River	Nacoochee, Ga	do	424.0
Do	Bean Creek	1 mile east of Nacoochee, Ga	do	12.3
Do	Chickamauga Creek	3½ miles northeast of Nacoochee, Ga	do	109.8
Jan. 14	Soque River	4 miles south of Soque, Ga	do	132.0
Do	Shoal Creek	¼ mile above mouth	do	50.1
Do	Soque River	7 miles south of Soque, Ga	do	202.2
Jan. 15	Hazel Creek	Demorest, Ga	do	94.8
Do	Whites Creek	7 miles west of Demorest, Ga	do	38.2
Do	North Prong of Mossy Creek.	Mossy Creek, Ga	do	51.1
Do	South Prong of Mossy Creek.	do	do	25.0
Do	Flat Creek	Glades, Ga	do	22.5
Jan. 16	East Prong of Little River.	2½ miles west of Glades, Ga	do	36.4
Do	West Prong of Little River.	4 miles west of Glades, Ga	do	52.4
Do	Wahoo Creek	4 miles east of Price, Ga	do	89.0
Do	Chestatee River	Newbridge, Ga	do	717.2
Aug. 17	Yahoola Creek	Bridge 1 mile northeast of Dahlonega, Ga.	do	241.0
Do	Tate Creek	1 mile southeast of Porter Springs, Ga	do	32.6
Aug. 19	Cane Creek	3⅝ miles northwest of Dahlonega, Ga	do	40.5
Aug. 29	Santee Creek	½ mile east of Santee, Ga	do	316.8
Do	Chattahoochee River	1 mile west of Nacoochee, Ga	do	605.6
Do	East Tessantee Creek	2 miles north of Cleveland, Ga	do	27.8
Aug. 30	Chestatee River	3 miles southeast of Dahlonega, Ga	do	744.1
Aug. 31	Crooked Creek	2¼ miles southwest of Dahlonega, Ga	do	9.0
Do	Chestatee River	Newbridge, Ga	do	1,141.3
Do	Yellow Creek	2 miles southeast of Newbridge, Ga	do	41.0

Discharge measurements of Etowah River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Jan. 7	Willieo Creek	¼ mile above mouth	B. M. Hall and assistants.	20.1
Jan. 8	Coopers Sandy Creek	1 mile north of Crabapple, Ga	do	9.0
Do	South Prong of Little River.	2 miles south of Freemansville, Ga	do	21.5
Do	North Fork of Little River.	2 miles north of Freemansville, Ga	do	13.4
Do	Smithwick Creek	½ mile east of Orange, Ga	do	8.2
Do	Buzzard Flopper Creek.	3 miles east of Orange, Ga	do	6.5
Do	Boardtree Creek	1 mile south of Creighton, Ga	do	7.2
Do	Settingdown Creek	Creighton, Ga	do	74.0
Jan. 9	Etowah River	¼ mile north of Hightower, Ga	do	512.4
Do	Yellow Creek	6 miles northeast of Hightower, Ga	do	32.0
Jan. 10	Amicalola River	Afton, Ga	do	166.4
Do	East Amicalola River.	Weir, Ga	do	58.3
Jan. 11	Nimblewill Creek	1 mile south of Randa, Ga	do	383.3
Do	Etowah River	5½ miles east of Randa, Ga	do	1,881.0
Jan. 17	Cogburris Creek	1½ miles above mouth	do	14.6
Do	Etowah River	Hightower, Ga	do	676.1
Jan. 18	Settingdown Creek	¼ mile above mouth	do	178.3
Do	Boardtree Creek	1 mile south of Creighton, Ga	do	9.8
Jan. 19	Willieo Creek	¼ mile above mouth	do	31.0
Aug. 31	Etowah River	1 mile west of Auraria, Ga	do	173.0

Discharge measurements of Cahaba River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Jan. 28	Hawkins Spring	¼ mile from Hawkins Station	K. T. Thomas	15.8
Jan. 29	Cahaba River	Sydenton, Ala	do	549.0
Mar. 28	Valley Creek	Adjers Station, Ala	J. R. Hall	378.0
Do	Blocton Creek	Blocton, Ala	do	107.0
Mar. 29	Cahaba River	¼ mile south of Sydenton Station, Ala	do	1,117.0
Do	Buck Creek	½ mile above mouth	do	179.0
Apr. 25	Cahaba River	2 miles east of Harrell, Ala	do	6,560.0

Discharge measurements of Tombigbee River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Feb. 16	Tombigbee River	Waverly, Miss	K. T. Thomas	6,726
Feb. 18	Luxapelila Creek	Columbus, Miss	do	957
Mar. 7	Yalabusha River	Grenada, Miss	do	1,336
Mar. 11	Luxapelila Creek	Columbus, Miss	do	2,459
Apr. 15	Big Black River	1 mile east of Goodman, Miss	do	614
Apr. 16	Luxapelila Creek	Columbus, Miss	do	873
June 26	do	do	do	109
Oct. 31	do	do	do	126

Discharge measurements of tributaries of Mississippi River.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Feb. 14	Sunflower River	Baird, Miss	K. T. Thomas	3,761
Feb. 15	Sakatouchee River	Mhoon Valley, Miss	do	559

Discharge measurements of Tallapoosa River and tributaries.

Date.	Stream.	Locality.	Hydrographer.	Discharge
1901.				*Sec.-ft.*
Jan. 7	Tallapoosa River	2 miles from Tallapoosa, Ga	Max Hall	329
Feb. 11	Wind Creek	About 4 miles above mouth	J. R. Hall	66
Do	Saugahatchee Creek	Thaddeus, Ala	do	453
Feb. 13	Blue Creek	½ mile from Susanna, Ala	do	117
Do	Chenehatchee Creek	3 miles above mouth	do	80
Feb. 27	Kowaliga Creek	Kowaliga, Ala	do	154
Mar. 5	Emuckfaw Creek	Near Zana P. O., Ala	do	113
Mar. 11	Moores Creek	1½ miles north of Dudleyville, Ala	do	29
Mar. 12	Chattahaspa Creek	1 mile south of Patillos crossroads, Chambers County, Ala.	do	203
Do	Cohoasoncsa Creek	2½ miles below and west of Milltown, Ala.	do	122
Do	Highpine Creek	½ mile south of Chambers and Randolph County line.	do	89
Do	Beaverdam Creek	1 mile north of Lovina, Ala	do	30
Mar. 13	Cornhouse Creek	Near Level Roads, Ala	do	31
Do	Wildcat Creek	Near Gay P. O., Ala	do	32
Do	Tallapoosa River	About 3 miles below confluence of Big and Little Tallapoosa rivers, at Blakes Ferry.	do	2,400
Do	Crooked Creek		do	183
Do	Hurricane Creek	1 mile north of Almond, Ala	do	29
Oct. 21	Tallapoosa River	Near Tallapoosa, Ga	Max Hall	119
Do	do	do	do	96

Discharge measurements of tributaries of Coosa River in Alabama.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Apr. 5	Choccolocco Creek	1½ miles north of Jenifer, Ala	J. R. Hall	1,170.0
Oct 16	Big Wills Creek	2 miles north of Attalla, Ala	F. A. Murray	107.3
Do	do	do	do	106.8

Discharge measurements of tributaries of Oostanaula River.

Date.	Stream.	Locality.	Hydrographer.	Discharge.
1901.				*Sec.-ft.*
Jan. 7	Mountaintown Creek.	3½ miles from Ellijay, Ga	B. M. Hall and assistants.	162.0
Do	Ellijay River	Ellijay, Ga	do	165.0
Jan. 8	Cartecay River	do	do	250.0
Do	do	Cartecay, Ga	do	207.0
Do	Anderson Creek	1 mile above mouth	do	37.0
Jan. 9	Tickanetley River	1 mile above mouth of Anderson Creek	do	43.5
Jan. 28	Jacks River	Near its junction with Conasauga River.	do	186.0
Do	Conasauga River	1 mile above mouth of Jacks River	do	119.0
Do	Sheets Creek	Just above mouth	do	12.0
Jan. 29	Sumach Creek	At junction of North and South prongs.	do	58.3
Do	North Prong of Sumach Creek.	Near junction of North and South prongs.	do	19.8
Do	South Prong of Sumach Creek.	do	do	38.5
Do	Mill Creek	Near Dunn, Ga	do	41.8
Do	Holly Creek	Near East Mountain, Ga	do	107.0
Do	Rock Creek	Ramsay, Ga	do	41.0
Aug. 19	Talking Rock Creek	Talking Rock, Ga	do	215.0
Do	Talona Creek	¼ mile above mouth	do	714.0

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DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 64

GOVERNMENT PUBLICATIONS
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ACCURACY OF STREAM MEASUREMENTS.—MURPHY.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps, showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93. in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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WATER-SUPPLY

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UNITED STATES GEOLOGICAL SURVEY

No. 64

WASHINGTON
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1902

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

ACCURACY

OF

STREAM MEASUREMENTS

BY

EDWARD CHARLES MURPHY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., December 30, 1901.

SIR: I have the honor to transmit herewith a manuscript prepared by Prof. E. C. Murphy, of Cornell University, Ithaca, N. Y., giving the results of investigations made by him into the accuracy of stream measurements as ordinarily conducted by the hydrographers of this Survey.

Professor Murphy was for some time resident hydrographer for eastern Kansas, and carried on in the field measurements of several rivers, being thus by actual practice thoroughly familiar with the operations of the hydrographic branch of the Geological Survey. Upon his removal to Ithaca Professor Murphy began a series of experiments, using the facilities offered by the hydraulic laboratory of Cornell University.

While the methods of river measurement at present in use are believed to be sufficiently accurate for the purposes of ascertaining the water resources of the United States, yet it is important to know their probable accuracy, and particularly the accuracy of the instruments which are commonly employed. Through such knowledge and experience gained from time to time it will be possible to improve upon the methods, in the interest of greater exactness or wider diffusion of the work.

I therefore request that this manuscript be published in the series of Water-Supply and Irrigation Papers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

ACCURACY OF STREAM MEASUREMENTS.

By Edward C. Murphy.

FACTORS CONTROLLING ACCURACY OF STREAM MEASUREMENTS.

The accuracy of a stream measurement depends largely upon the accuracy with which the cross-sectional area and the velocity are measured. There is no special difficulty in measuring the first factor, but the second factor—the velocity—is very difficult to measure, chiefly for the reason that it is constantly changing. It not only varies from the surface to the bottom and from one bank of the stream to the other, so that it is necessary to measure it at many points, but it is constantly changing at every point, even when the cross-sectional area and the discharge (and consequently the mean velocity) remain constant. Several experimenters have observed the phenomenon of "pulsation of moving water," and a few have tried to measure it, but as yet little is known of the magnitude and frequency of the pulsations or of the laws governing them. J. B. Francis says:[a] "It is observed that there is a continual change in all parts of these channels, although there may be no sensible change in the volume of water flowing and consequently in the mean velocity." Captain Cunningham says:[b] "One of the most important conclusions of modern experiments is that the motion of water, even when tranquil to the eye, is extremely unsteady, so that there is no definite velocity at any point, but the velocity varies everywhere, largely from instant to instant. * * * It is analogous to the unsteady motion of wind, which is exemplified by the swaying of wind vanes and by the fluttering of pinions." D. F. Henry says:[c] "All water in motion has an intermittent velocity, increasing and decreasing according to some undiscovered law," and Henry found this true of streams of all sizes, from small mill races to the great St. Lawrence River.

A knowledge of these phenomena is evidently of vital importance in making and computing stream measurements. If only a few observations of velocity are made, these may all, or nearly all, be

[a] Trans. Am. Soc. Civ. Eng., Vol. VII, p. 111.
[b] Recent Hydraulic Experiments: Proc. Inst. Civ. Eng., Vol. LXXI, p. 7.
[c] Jour. Franklin Inst., Vol. LXII, p. 323.

made at a time of maximum impulse, and thus the measured mean velocity be too large; or it is possible that most of the observations may be made at a time of minimum impulse, and thus the mean velocity be too small. They also have an important bearing on the kind of instrument best suited to measure the velocity, as some—the float rod, for example—give the velocity of a single impulse, while others, as the current meter, show the average velocity due to all the impulses during the observation.

The motion of water in an open channel is not, however, simply a succession of impulses. On the contrary, it is exceedingly complex, very different from the uniform flow in parallel straight lines that is assumed in deriving the common hydraulic formulæ. When closely observed the water of the most undisturbed streams is seen to "boil" and swirl and to be very unsteady, some particles moving up, others down, others across, but all as a rule having a general motion downstream.

The accuracy of a discharge measurement also depends much upon the physical features of the stream at the discharge section or point of measurement. When possible this section should be on a straight reach and far enough from a bend to be out of its influence, the bed should be permanent and not stony, and the slope and wetted perimeter such that at high and low stages of the stream the velocity in all parts of the section will be easily measurable. The banks should be sufficiently high not to be overflowed at flood stage, and the section should be free from the influence of milldams and bridge piers. In addition, economy requires that the section selected be easily accessible from a railway station and that there be a person living near who will read the elevation of the water surface at stated times. Seldom if ever are all of these conditions even approximately satisfied. Scour of bed in some cases and silting in other cases give much trouble; too great a velocity at high stages and too low a velocity at low stages to measure with accuracy are common difficulties; and milldams often give trouble, on account of storage and irregular discharge through their wheels; so that the hydrographer must make the most of the best location he can find, always having in mind the desirable and the undesirable qualities.

Rapid fluctuations of the water surface or river height during measurement and the condition of the velocity-measuring instrument are other factors which affect the accuracy of a stream measurement.

A great many discharge measurements of natural and artificial channels have been made with various kinds of instruments and in various ways. The earlier ones were made with crude instruments, and in some cases the surface velocity only was observed, the mean velocity being computed from a formula which we now know is not correct. Very little appears to have been done in the way of determining the degree of accuracy of the measurements. Even when the

experimenter has used two or more instruments to measure velocity, he does not appear to have made simultaneous measurements with different instruments, or employed different methods with the same instruments, in order to test the accuracy of the results.

These matters are all discussed in detail on the following pages.

METHODS OF MEASURING VELOCITY.

The methods that have been used for measuring velocity may be divided into two general classes—the direct and indirect. The direct methods include all ways of ascertaining the velocity of water from bodies floating in it, such as surface floats, float rods, double floats, etc. The indirect methods include measurements with the current meter, pressure plates, the thermometer, etc., by which the velocity of the water is inferred from its impact, its pressure, or its temperature. Measurements by the direct methods are simple, requiring only the measurement of the time that it takes a body in the water to move over a certain distance, while in the indirect methods the constant of the instant must first be found from experiment. The latter methods are, however, theoretically better than the former.

By the direct methods the mean velocity of a comparatively few particles of water is found for the time required for the float to move between the sections of observation—that is, the float is acted upon by the particles about it during the time it is passing over the measured distance. It is carried along by a single impulse of the water, and is not affected by the succeeding impulses, which may be greater or less than the impulse which moves it. Instruments of the second class, on the other hand—as, for instance, the meter—measure instantaneously the velocity of all the particles that strike it during the observation. If there were no pulsations of water, and if the particles following one another at any given point moved with uniform velocity, then the direct methods might, in the absence of wind, give good results; but since all moving water, even the most undisturbed, has these pulsations, velocity measurements by the indirect methods are decidedly more accurate than those by the direct methods. One measurement with a current meter is worth several measurements with floats.

There is another reason why indirect measurements are preferable to direct measurements. Since in the latter the mean velocity is found over a certain distance, usually from 50 to 200 feet, it is necessary to know the mean area over that distance, and this requires the measurement of many cross sections between the upper and the lower section, while by the indirect methods the measurement of only one area is required.

DIRECT METHODS.

SURFACE FLOATS.

Surface floats are small, light bodies, such as wood or wax, which float on the surface of the water and can readily be seen from the shore. Measurement by this means is rapid, but the velocities obtained may be greatly in error, due to the action of wind on the float. At best it only indicates the velocity for a short time of a comparatively few particles of water, and the mean velocity must be found from the relation between surface velocity and mean velocity, which is not well established. The time consumed by the floats in passing over a measured distance—usually from 50 to 200 feet—is observed, and the distance divided by the observed time gives the surface velocity at that point for that time.

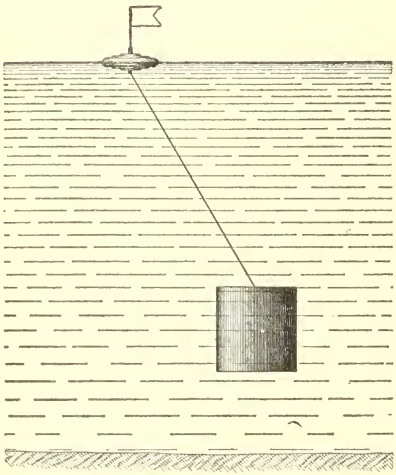

FIG. 1.—Double float used by Ellis in Connecticut River survey in 1874.

This method was used by Dubuat in 1779 in gaging the Canal du Jard, in France, and in 1782 in gaging the Haine River, Belgium; by Trechsel, in 1825, to gage the Outer Aar, near Thun; by Wampfler, in 1867, to gage the Simme Canal, Switzerland; by Harlacher, in 1881, to gage the Elbe, in Bohemia (at high water only); by Ellet, in 1858, in gaging the Ohio; and by others.

DOUBLE FLOATS.

The double float consists of a light surface float and a subsurface float somewhat heavier than water connected to it by a cord or a small rope. The office of the upper float is to support the lower float and indicate its position. The connecting cord can be lengthened at will and the lower float be placed at any desired depth. Fig. 1 shows the double float used by T. G. Ellis in the Connecticut River survey in 1874. This subsurface float was a hollow annulus of tin $8\frac{1}{2}$ inches high, $8\frac{1}{2}$ inches outside diameter, and $7\frac{1}{2}$ inches inside diameter. Two brass wires were soldered across the bottom at right angles to each other, to which was attached 28 ounces of lead as a sinker. Two other wires were soldered at right angles to each other at the center, to which the connecting cord was attached. The surface float was an ellipsoid of tin 6 inches in diameter and $1\frac{1}{2}$ inches thick, with a cork in the top holding a small flag and an eye in the bottom for the connecting cord. The connecting cord had a diameter of 0.036 inch.

The method of measuring stream flow by double floats as used by

Humphreys and Abbot in gaging the Mississippi River in 1851 and 1858 is substantially as follows:[a] A suitable place was selected on the river, a base line 200 feet long was measured off on one bank parallel to the axis of the current, and a section at each end of this base was marked out at right angles to it. The time consumed by each float in passing between these sections and the position of each float when it passed them were noted by four men, two at each end of the base, each party having a stop watch and a theodolite. At a signal from the engineer the floats were placed in the river from a boat about 100 feet above the upper section and were picked up by a man in a boat some distance below the lower section. At the instant a float passed the upper section a signal was given, the watches were started, and the angular position of the float was read with both theodolites. The instant the float passed the lower section a signal was again given, the watches were stopped, and the angular position of the float was again read with both theodolites. These readings gave the distance of the float from the base line when it passed the sections and two independent measurements of the time consumed by it in passing between the sections. Soundings were taken at the end sections and at one or more intermediate sections, from which the area of the mean section was computed.

In some cases where this method has been used the base was 300 feet long and the time of run of the floats has been recorded on a chronograph.

This method has its advantages and its disadvantages. In very deep rivers, such as the Mississippi, or in streams carrying weeds and grass, it is almost the only available method. Humphreys and Abbot, in their report on the Mississippi River, say:[b] "Saxton's current meter was tried but found to be unsuited to measurements in a river of such great depth and violence of current. Only double floats were found to give reliable results."

In regard to the disadvantages, D. F. Henry, who had charge of the field work of the gaging of the outlets of the Great Lakes and who has used this and other methods for deep rivers, says:[c] "All the objections to the surface float apply with greater force to the double float, and additional ones peculiar to itself." It is impossible to determine the exact position or depth of the lower float. Its position is determined from that of the surface float, but it varies with the direction and velocity of the wind and the length of the cord connecting the floats. The depth of the float is determined from the length of the connecting cord, but on account of the upward "boiling" motion of the water, and also the pressure of the water on a long connecting cord, the depth may be much less than the length of the cord. The upper float may drag the lower one or be dragged by it. At best

[a] Report on the Mississippi River, by Humphreys and Abbot, p. 224.
[b] Op. cit., p. 225.
[c] Jour. Franklin Inst., Vol. LXII, p. 167.

it can only give the velocity of a few particles for a short space of time.

This method of gaging was used in the Mississippi River and tributaries from 1857 to 1881. Since that time the current meter has been largely used. In 1869 it was used in conjunction with the current meter for gaging the outlets of the Great Lakes. It was also used by T. G. Ellis in 1874 in his survey of the Connecticut River, in conjunction with the current meter, and by Gordon in 1873 to gage the Irawadi River. For comparisons of accuracy of this method with others, see pages 47 to 51.

FLOAT RODS.

Professor Cabeo[a] was the first to use the float rod for measuring velocity. This was in 1646. The rod is of wood or tin, from 1 to 2 inches in diameter, weighted at the lower end so as to float vertically. Its lower end should nearly touch the bottom and its upper end project a few inches above the surface of the water, so as to be visible. The method of using float rods as followed by the writer in 1900 in the New York State canal survey is as follows: Two surveyor's 100-foot chains were stretched across the canal from 10 to 30 feet apart and at right angles to the axis of the canal. Fifteen feet above the upper chain a rope was stretched across the canal, and to this a boat was attached by pulleys, so that a man in the boat could easily move himself back and forth by pulling on the rope. Another rope was stretched across the canal from 6 to 8 feet below the lower chain and a boat operated from it in a similar way. The floats were put in by the man in the upper boat, two at a time and about 5 feet apart, and were observed by him until they passed the upper chain, when he called to the recorder the position of each. As they passed under the lower chain the man in the lower boat called out their position, and when they reached his boat he took them out of the water and brought them to the shore. An observer with two stop watches noted the time of passage of each pair of floats between the chains. A short run was used on account of the low velocity of the water.

The advantages and disadvantages of the method may be summed up briefly as follows:

Advantages.—For artificial channels of moderate and uniform depth and with floating grass and weeds this is probably the best method to use. The advantages of float rods as given by Captain Cunningham, who has used them to a large extent in his gagings of the Ganges Canal, are as follows:[b] (1) They interfere less with the natural motion of the water; (2) they measure velocity direct; (3) they can be used in a stream of any size; (4) they are not affected by silt and weeds; (5) they measure forward velocity; (6) they can be made by a common workman; and (7) they are cheap.

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[a] See Report of New York Barge Canal, 1901, p. 869.

[b] Proc. Inst. Civil Eng., Vol. LXXI, p. 1.

Disadvantages.—The rods are affected to some extent by wind; they do not give mean velocity, but velocity of impulses; they can not be used in deep streams or in streams of rough or irregular bed, and they are expensive to operate.

Float rods have been used by Cunningham, on the Ganges Canal, in 1880; by Francis, in 1852, on a canal at Lowell, Mass.; by Buffon, on the Tiber River, in 1821; by Krayenhoff, on the Rhine, in 1812; and by the Mississippi River Commission, on the Upper Mississippi, in 1881.

FLOAT FRAME.

Hirn used, for obtaining velocity, a light frame of wood which nearly filled the cross section of the channel, but there are practical difficulties in the way of the use of this instrument.

INDIRECT METHODS.

The following instruments and methods have been used at one time or another for measuring velocity indirectly. Several of them are now of historical interest only.

FLOAT WHEEL.

The float wheel was used by Borda and Dubuat for measuring surface velocities. That used by the latter was 2 feet in diameter, and recorded the revolutions on dials.

PRESSURE PLATE.

In 1779 Gaunthy invented the pressure plate, which consists of a disk of metal opposed to the pressure of water, the velocity being computed from the weight necessary to keep it vertical. The tachometer used by Brünings to gage the Rhine and the one used by Racourt in his gagings of the Neva were made on this principle. Captain Boileau also used a pressure plate in his tachometer.

BOX WITH HOLE IN SIDE.

A box with a hole in the side was used by Grandi in 1730 to measure velocity. It was lowered gradually from the surface to the bottom and raised again at the same rate, the velocity being inferred from the amount of water in the box.

HYDROMETRIC TUBE.

This instrument was used by Captain Boileau in 1850. It consists of a glass tube suspended in a frame, having a full-sized opening at one end and a small opening at the other end. The tube is filled with water and a bubble of air, and is placed in the water with the small end upstream. The large end is then opened and the time required for the bubble to traverse the tube is noted. From this time and the areas of the ends of the tube the velocity is computed.

HYDROMETRIC PENDULUM.

This instrument was used by Castelli in 1628. It consists of a ball suspended from the center of a graduated arc. The velocity is computed from the weight of the ball and the angle of the string when the water impinges on it.

THERMOMETER.

Leslie used a thermometer for measuring velocity. The principle of this method is that the temperature of water in motion is greater than the temperature when at rest.

PITOT TUBE.

This instrument was invented by Pitot in 1730. Fig. 2 shows it as improved and used by Darcy and Bazin.[a] It consists essentially of two tubes, one drawn to a fine point and pointing upstream, the other straight and with an opening at the lower end the size of the tube. The air in both tubes is partly exhausted, so that the water columns will rise to a convenient height. The velocity is found from the difference in the readings of the water columns. Like floats, this is an impulse-measuring instrument, but in using it both maximum and minimum impulses are observed and a mean is found. After the instrument is in place and the stop cocks R and R' are opened one of the observers applies his mouth to the tube O, removes the air until the surface of the water in the tubes stands at a convenient height to read, and then closes the upper cock (R). He observes the columns until they reach a maximum height, when he closes the cock R' and reads the surface of both columns; then he opens the cock R and observes the surface of both until the columns reach a minimum position, when he closes cock R' and reads both surfaces again. He now has a maximum and a minimum reading of each column, from which he makes the following deduction: If a' is the maximum reading of column A, and b' is the maximum reading of column B, and a'' is the minimum reading of column A, and b'' is the minimum reading of column B, then $a'-b'=d'$, the difference for the maximum impulse, and $a''-b''=d''$, the difference for the minimum impulse, and $\frac{d'+d''}{2}$ is the mean difference of the column readings for the two impulses. Two or three sets of these readings are taken at each point. Then if $\Sigma\frac{d}{2}$ is the mean of the values of these column differences ($\Sigma d= d'+d''+ \ . \ . \ .$), the velocity at that point is given by the formula $V=c\sqrt{2g\Sigma\frac{d}{2}}$, c being the coefficient found by rating and g the accel-

[a] Recherches hydrauliques, entreprises par M. H. Darcy continuées par M. H. Bazin. Première partie de Recherches expérimentales sur l'écoulement de l'eau dans les canaux découverts: Extrait des Mémoires présentés par divers savants à l'académie des sciences de Institut Impérial de France, Paris, 1865, Vol. XIX, Pl. XVII, fig. 5.

eration of gravity. The velocity can very quickly be found by one accustomed to using the instrument. The accuracy of V depends on that of c and on $\sqrt{\Sigma d}$, the greater the number of d's, or sets of observations, the more nearly accurate will be the value of V.

CURRENT METER.

The current meter had its beginning in the float wheel used by Borda and Dubuat to obtain surface velocities. In 1790 Waltman modified this wheel so that it could be used below the surface. His meter had helicoidal blades and an endless screw on its axis, which by gearing into a train of wheels caused a record of the number of revolutions of the wheel to be made on dials. It was moved up and down on a rod the lower end of which was driven firmly into the river bed. The recording apparatus was thrown in or out of action by a pull on a string. It was necessary to lift the meter to the surface to read the revolutions, which was a great drawback to its use, as was also the fact that dirt in the water retarded the train of wheels. Lepont sought to remove these difficulties by bringing the recording apparatus to the surface, away from the dirty water and where it could be read without lifting the meter. He did this by introducing a

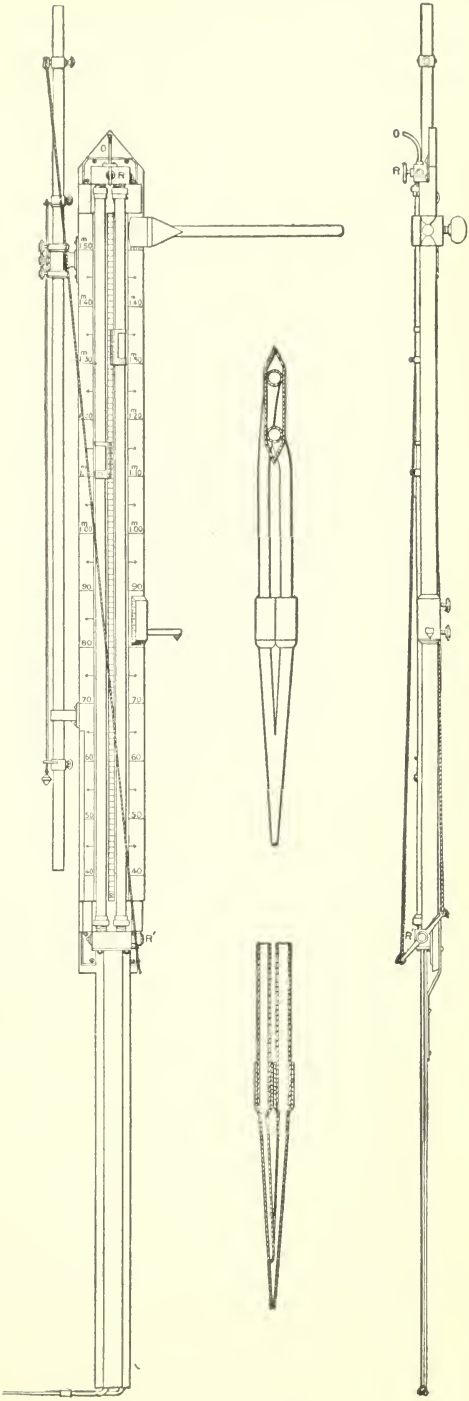


FIG. 2—Pitot tube.

vertical shaft or rod with beveled gearing, but this increased the friction so that it could only be used in shallow water. Baumgarten, Saxton, and others following modified its form somewhat, but did not materially improve it. Brewster made one in which the axis of the meter was a long screw and the revolutions were given by the distance the wheel traveled along this screw. The friction was thus

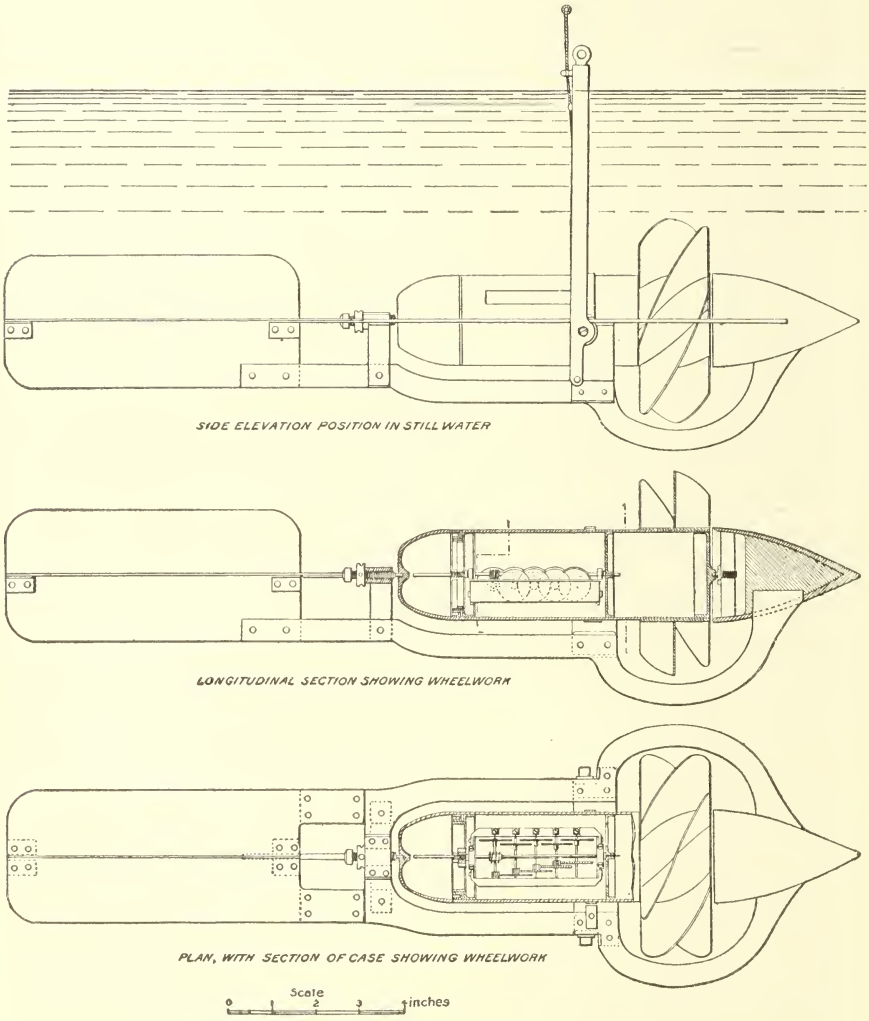
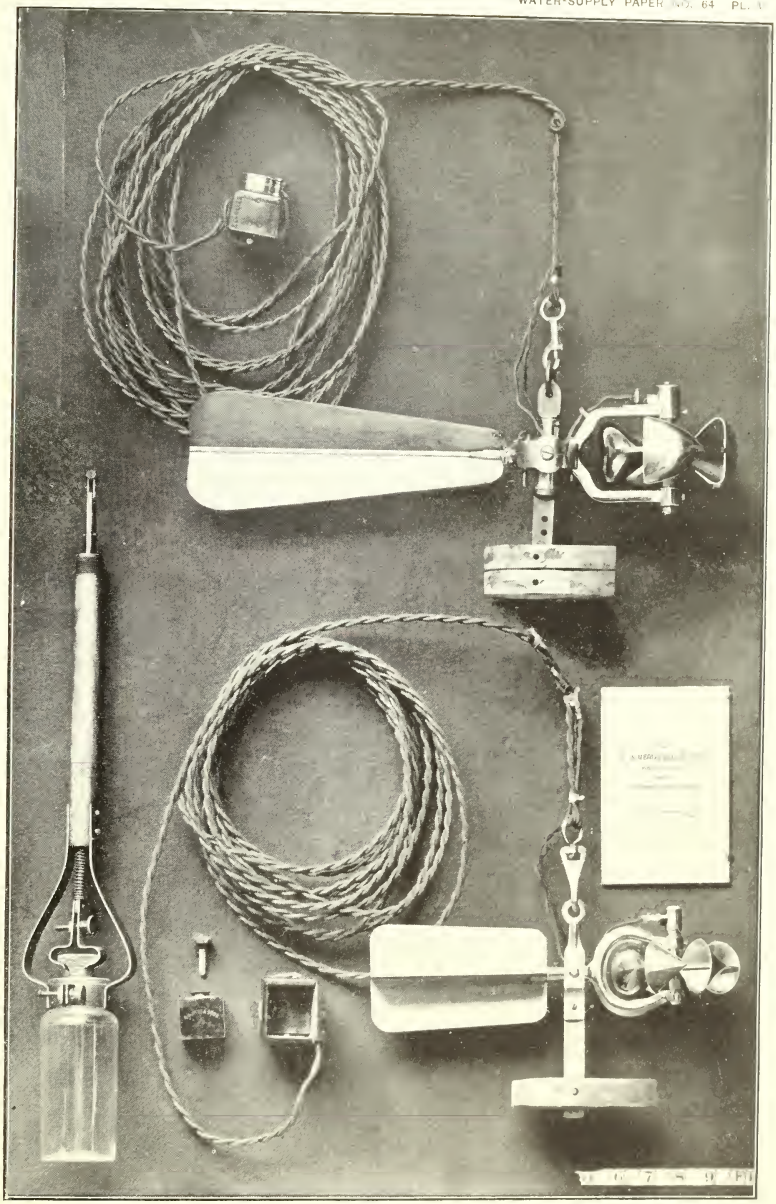


FIG. 3.—Moore current meter.

lessened, but the meter had to be stopped before the wheel traveled the whole length of the screw. It was a long step in advance that was taken by D. F. Henry when he applied an electric recording device to the meter, for by it the difficulties that Lepont and others sought to avoid are very successfully overcome, the friction of the train of recording wheels being entirely done away with. If a recording device



PRICE ELECTRIC CURRENT METERS.

is used it is worked by a spring and not by the meter, and, furthermore, it is not necessary to lift the meter to the surface to read the number of revolutions, which are recorded electrically, or may be

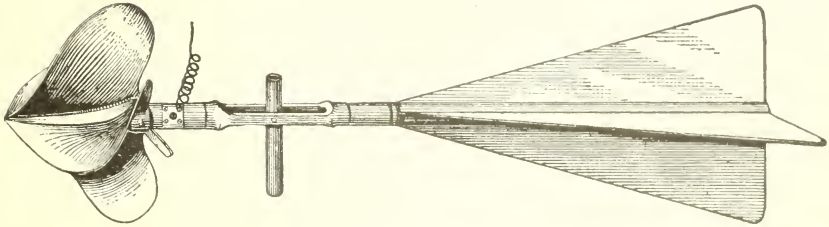


FIG. 4.—Haskell current meter.

counted from the indications of a buzzer. The electric meter as used by Henry is shown in fig. 10, page 34; that used by Moore in fig. 3.

Meters in use at the present day may be divided into two classes: (1) Those in which the revolving part turns about a horizontal axis, and (2) those in which it revolves about a vertical axis. The former class is illustrated by the Haskell and Fteley meters, shown in figs. 4 and 5, respectively, and the latter class by the Price meter, shown in Pl. I. Meters of the latter class have some advantages over those of the former class: First, friction is usually less, since it nearly all comes on one point, and this point can be protected from the action of grit in the water and from jars; and, second, for a given high velocity the wheel will not revolve as rapidly as the wheel of a meter of the first class under the same conditions, and at the same time the wheel will start in a less velocity than will the wheel of a meter of the former class, so that both low and high velocities can be measured more accurately with meters of the second class than with those of the first class. For example, by comparing the rating table of Haskell meter No. 3 on page 81 with that of small Price meter No. 363 on page 42, we find that the former requires a velocity of about 0.20 foot per second to start it, and that it makes 6.5 revolutions per second in water having

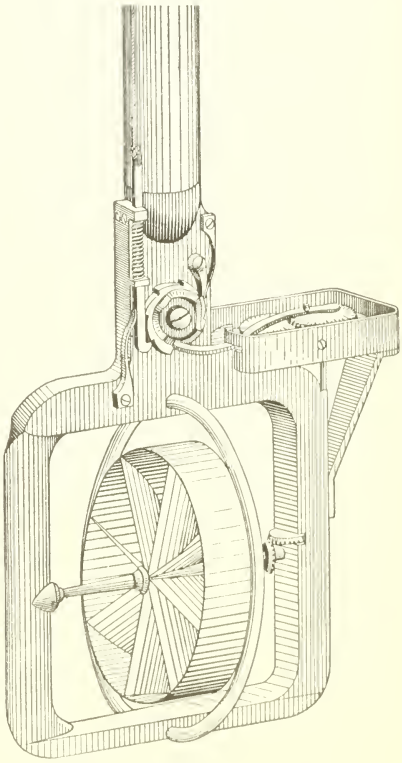


FIG. 5.—Fteley current meter.

a velocity of 7 feet per second, while the latter requires a velocity of about 0.06 foot per second to start it and makes only 3.02 revolutions in water having a velocity of 7 feet per second. A rate of 3 revolutions per second can easily be recorded or counted, but a rate of 6.5 revolutions per second can not be counted or easily recorded.

The disadvantages of the current meter are, briefly, as follows: (1) It can not be used where there is much floating grass or weeds, as on canals where the weeds are cut and allowed to float in the water, float rods being much better in such cases; (2) it requires rating before use and frequently thereafter; and (3) it must be used with care. These last two conditions, however, are true for all instruments used for measuring velocity indirectly.

The meter without some electrical device for indicating to the observer the revolutions in a given time, and which must be lifted out of the water to read the revolutions, is a thing of the past. Too much time is lost in making the readings. The acoustic meter is not a success. The clicks are not sufficiently loud to be heard when the water is deep and the place noisy.

The advantages of the meter are as follows: (1) It gives integrated or mean velocity (any kind of a float gives the velocity of a comparatively few particles at some stage of a pulsation of the water, not mean velocity); and (2) it can be used on streams of all sizes.

For large streams the choice of instruments is between the current meter and the double float, and the meter is preferable except where a large amount of weeds and grass is carried along in the water. For artificial channels the choice is between the meter and the float rod, and the meter has the preference except where there is a considerable amount of floating weeds, and possibly for very slow velocities also, but the latter is still in doubt. For velocities of 0.25 foot per second the meter will give the mean velocity as accurately and more rapidly than the rods, and at less cost, for at least four persons are necessary with the rod method, whereas one person, or at most two persons, can make the gaging with the meter, and the expense of moving the equipment from place to place is much greater for the rods than for the meter.

SLOPE FORMULA.

The velocity of a stream can be computed from measurements of the slope of the surface, the dimensions of the cross section, and a knowledge of the roughness of the bottom and sides. The formula which is now almost universally used for this purpose was devised by Kutter in 1869[a] and is as follows:

$$V=\left[\frac{41.6+\frac{1.811}{n}+\frac{.00281}{s}}{1+(41.6+\frac{.00281}{s})\frac{n}{\sqrt{Rs}}}\right]\sqrt{Rs}$$

[a] Flow of Water in Rivers and Other Channels, by E. Ganguillet and W. R. Kutter.

In this formula V=velocity, in feet per second; s=surface slope$=\frac{h}{l}$, h being the fall of the surface in the distance l; R=hydraulic radius$=\frac{F}{w}$, F being the cross-sectional area and w the wetted perimeter; and n a ratio whose value varies from 0.009 for a well-planed wooden channel to 0.035 for a channel overgrown with weeds or covered with stones.

This formula is said to apply to streams of all sizes, from creeks and sewers to large rivers like the Mississippi, its constants being determined from Bazin's gagings of small channels, from Humphreys and Abbot's gagings of the Mississippi River, from Cunningham's gagings of the Ganges Canal, and from gagings by many others.

The disadvantage of the method is that it is very difficult to measure accurately the surface slope (s) of large rivers. T. G. Ellis says[a] that on the Connecticut River the slope of parts 100 to 400 feet long was very carefully measured and the discharge computed, using the best modern slope formulæ. The discharge found from these formulæ differed by 50 to 250 per cent from that found by gaging. He thinks the slope is so uncertain an element that slope formulæ are of little value. Captain Cunningham, after an examination of five hundred slope measurements of the Ganges Canal, says:[b] "It [the slope of surface measurement] is so delicate a matter that the results are of doubtful use." He found that the slope was very different at different parts of a reach from 1 to 2 miles long, and that the slope at opposite sides differed 50 per cent. Ellet says,[c] in regard to the slope of the Mississippi River: "It not unfrequently happens that while the mass of the water which its channel bears is sweeping to the *south* at a speed of four or five miles per hour, the water near the shore is running *to the north* at a speed of one or two miles per hour. It is no unusual thing to find a swift current and a corresponding fall on one shore toward the south, and on the opposite shore a visible current and an appreciable slope toward the north."

Only in very rare cases is it advisable to use this method.

MEASUREMENT OF SURFACE FLUCTUATIONS.

Any change in the elevation of the surface of a stream affects the discharge in two ways: The cross-sectional area is changed and as a rule the velocity also is changed.[d] It is necessary, therefore, in accurate work to measure the surface fluctuations with great care. Wave action, due to wind or other causes, should be eliminated.

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[a] Trans. Am. Soc. Civ. Eng., Vol. XI, p. 23.

[b] Proc. Inst. Civ. Eng., Vol. LXXI, p. 11.

[c] Report on the Mississippi River, by Humphreys and Abbot, p. 218.

[d] On some streams there are places where the mean velocity remains nearly constant for several feet variation in stage of river. This is true of the Verdigris River at Liberty, Kans. See Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. IV, p. 374.

There are two classes of instruments in use at the present time for indicating surface elevations: (1) Self-registering gages, which give a continuous record of the changes in surface elevation; and (2) a fixed scale from which the elevation of the surface is read at any time, or a moving scale with a fixed index from which the elevation of the surface is read.

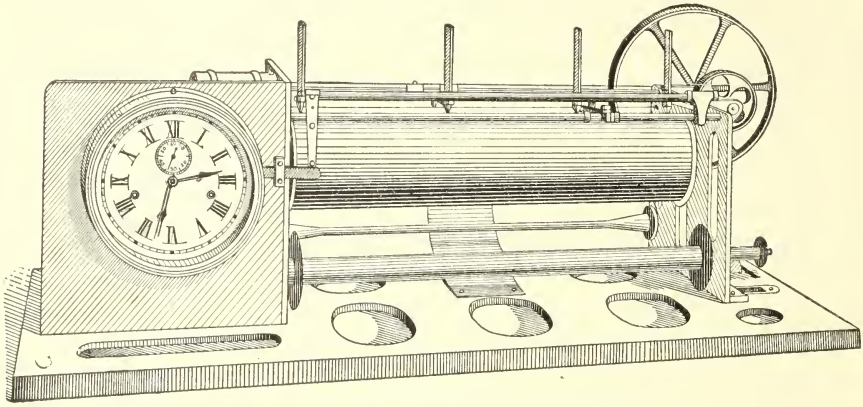

FIG. 6.—Self-registering water gage used by United States Lake Survey.

The United States Lake Survey self-registering water gage, shown in fig. 6, is a good illustration of instruments of the first class. The center pen is connected to a float on the surface of the lake, and its

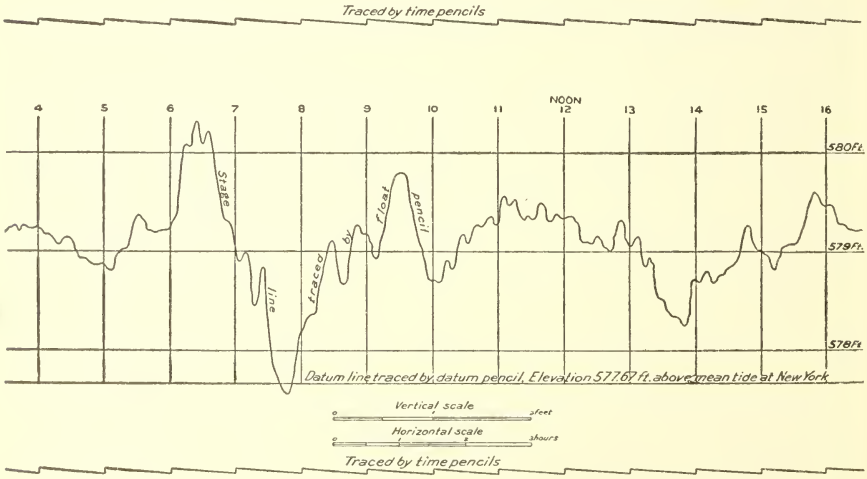

FIG. 7.—Record made by self-registering water gage used by United States Lake Survey.

motion is proportional to the change in elevation of the float. This motion is traced by the pen on a sheet of paper on the drum, which is moved at a uniform rate by clockwork. The two outer pens record the time. Fig. 7 is a reproduction of the record made by this instrument on May 17, 1899. The elevation of the surface at any instant is

given by the corresponding ordinate of this curve. This figure illustrates the need of an accurate record of the change in stage, for it shows a change of surface elevation of 2.5 feet in one and five-tenths hours.

The hook gage, shown in fig. 8, is a good illustration of a gage of the second class. The frame is fastened firmly to a post in the water, and the elevation of the zero reading is determined. By turning the milled nut the hook is raised until its point comes to the surface of the water. This can be done very accurately in still water, by means of the little spot of light on the point of the hook. The scale is then read, and from it the surface elevation is found.

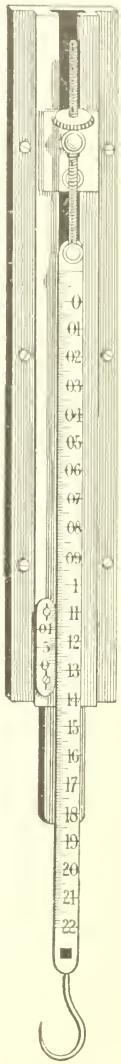

FIG. 8.—Hook gage for measuring surface fluctuations.

The water gage used by the United States Board of Engineers on Deep Waterways in 1897–98, on the Niagara River at Buffalo, N. Y., was of the box-with-float type. The box was of wood, 7 inches high, 7 inches wide, and 7 feet long, with a closed bottom and a removable cover. The box was fastened firmly in the water, with half its length below the surface. Water was admitted to it through one or more of three ¼-inch holes, allowing the float to change its elevation as the river stage changed and at the same time eliminating the effect of waves. The float was a 2-quart bottle with a 7-foot staff, marked to feet, tenths, and hundredths, wedged into it. This staff extended up through the cover, and was marked so as to give the rise of the water surface above a certain plane as read at the cover of the box.

VERTICAL VELOCITY CURVES.

The relation between velocity and depth in a vertical section of a stream parallel to the thread of the current, or the vertical velocity curve, is very desirable. From such a curve the ratio of velocity at any depth to mean velocity can easily be found and the discharge be computed from observations at one depth only in verticals.

Much effort has been expended in investigating this relation and the change in it for change in river stage. As might be expected, the results of experiments in this direction do not agree. Each investigator adopts a new form of curve to fit his observations. In 1791 Waltman made some observations on the Rhine, from which he concluded that the vertical velocity curve is a reversed parabola with its vertex below the bed of the river. In 1820 De Fontaine found the greatest velocity of the Rhine to be at

the surface. He states that two inclined right lines intersecting about mid depth satisfy his vertical-curve observations. In 1824–1826 Racourt made observations on the Neva River, from which he concluded that this curve is an ellipse whose minor axis is a little below the surface. Funk adopted a logarithmic curve for his observations on the Weser in 1820. In 1844 Boileau found this curve for a small canal to be a parabola with its axis near the surface. Darcy and Bazin found it to be a reversed parabola for their experiment canal, the perimeter changing with the character of the bed. For the Mississippi River, Humphreys and Abbot found it to be a parabola whose axis is three-tenths depth below the surface. Henry found it to be an ellipse for the St. Clair River, while Baumgarten says that no simple curve will fit the observations in a vertical. From the results of these investigations and others that might be mentioned it appears that the shape of the vertical velocity curve depends much on local conditions, as roughness of bed, slope, ratio of depth to width, wind, obstructions, etc. Two facts must be borne in mind, however: (1) All the vertical velocity-curve observations obtained with a single meter will not when plotted fall on any one line, but the results will be scattered more or less, and it will be possible to pass a number of curves among them, one satisfying the observations about as well as another; and (2) there is some part of each of the curves mentioned which if placed by the side of some part of another curve will coincide with it closely, so that it is quite possible for any or all of these curves to fit more or less closely a set of imperfect vertical velocity-curve observations.

There are two methods of obtaining vertical velocity curves with current meters: (1) The single-meter method, and (2) the multiple-meter method. In the former a meter is held at as many points in a vertical as desired—at each tenth of the depth, for example—for a time sufficiently long to eliminate the effect of pulsations. This requires one or more hours to a vertical, during which time a permanent change may occur in the mean velocity. In the latter method, however, this difficulty is overcome, for enough meters are used simultaneously to give the whole curve in one operation.

In the vertical velocity-curve work on the St. Clair River, under the direction of E. E. Haskell, United States assistant engineer, eleven meters were used at a time. These were fastened between two cables, which were attached to a 200-pound sinker at the lower end and to a drum at the upper end, and operated from a catamaran. The lower meter was 1.75 feet above the bottom; the other ten were placed at each tenth of the depth. Each meter was connected with an electric register, and by means of a switch all of the circuits could be opened in one operation. The observer, with a stop watch in one hand and the switch handle in the other, started the watch and at a given instant closed all of the circuits through the meters and registers. At the end of the observation he stopped the watch and opened the circuits

at the same instant. One observation of six hundred seconds was made with the meters arranged as described, and from one to ten others of one hundred seconds each with the meters arranged in other ways in each vertical.

There should be some criterion for the rejection of doubtful observations and the grouping of vertical velocity curves. The following table gives the position of the vertex of sixty-nine vertical velocity curves obtained on the Mississippi River by Humphreys and Abbott, and illustrates this need:

Table showing position of vertex of vertical velocity curves obtained on Mississippi River.

Depth.	First series.		Second series.		Total.	
	Number of verticals.	Number of floats.	Number of verticals.	Number of floats.	Number of verticals.	Number of floats.
Surface	12	63	8	17	20	80
One-tenth	11	46	1	2	12	48
Two-tenths	5	33			5	33
Three-tenths	3	20	1	3	5	23
Four-tenths			4	9	4	9
Five-tenths	2	22	1	3	3	25
Six-tenths	5	30	1	3	6	33
Seven-tenths			6	18	6	18
Eight-tenths			6	15	6	15
Nine-tenths			2	5	2	5
Bottom	1	8			1	8
Sum	39	222	30	75	69	297

The vertex of 34 per cent of the curves in the foregoing table is at or below mid depth of the river. Using all of them the vertex is three-tenths depth below the surface. This combination of curves so dissimilar is, to say the least, very questionable. Those in which the vertex is at or below seven-tenths depth should be rejected, or at least not combined with the others, for they are due either to errors or to abnormal conditions, and should not be used in deriving a general law.

Vertical velocity curves obtained in different parts of the discharge section for different depths are frequently combined by combining the velocities at each tenth of the depth. This assumes that the curves are similar in all parts of the discharge section, which is not true except in rare cases.

There is very little available data on the change in the vertical velocity curve with change of river stage. In the data on this point that have come to the writer's observation the change in stage is small and the inference to be drawn not conclusive. The effect of roughness of bed decreases, while that of slope and hydraulic radius increases with increase of stage. The effect of these on the shape of the curve can only be determined by careful measurements in which there is a wide range of stage.

PULSATION OF MOVING WATER.

We have already called attention to the fact that one of the reasons it is difficult to measure accurately the velocity of water is that the velocity at any given point in a stream is constantly changing. This is true of both natural and artificial channels of all sizes. Captain Cunningham, who observed this pulsation of moving water in his experiments on the Ganges Canal, of India, states that he considers fifty repetitions with float rods necessary in order to get a good average value of the velocity in one vertical of a canal.[a] J. B. Francis has made numerous measurements of the velocity with float rods in a rectangular wooden flume at Lowell, Mass., every precaution being taken to have the usual causes of irregularity of motion suppressed. The time of run was obtained by the use of an electric telegraph and a chronograph, and the depth was very carefully measured with a hook gage, and yet he found that the velocity shown by these floats varied from 8.57 per cent above the mean to 11.4 per cent below it. He says: "Similar and probably greater variations occur in different parts of the depth from the same cause."[b] Adam Baum has made some observations on the variation of velocity in the Rhine near the Bridge of Constance.[c] He fixed a current meter in the river and noted the time of each 100 revolutions of the meter wheel for a period of two hours. The results show a continual change in the velocity for a constant depth of water. He concludes that for an accurate measurement of velocity it is necessary to extend the observations over a period of one hour at each point.

Professor Unwin has made some observations with a current meter on the variation in velocity in the river Thames.[d] He noted the time of each 100 revolutions, and upon plotting the time and the revolutions found that they gave a very irregular curve. The mean of each 500 revolutions, however, when plotted with the corresponding time gave a rather regular curve. The following are some of the results of Professor Unwin's observations:

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[a] Proc. Inst. Civ. Eng., Vol. LXXI, p. 8.
[b] Trans. Am. Soc. Civ. Eng., Vol. VII, p. 117.
[c] Proc. Inst. Civ. Eng., Vol. LXXI, pp. 456-459.
[d] Op. cit., pp. 348, 349.

Variation in velocity at three points of a vertical of Thames River as found by Unwin.

At 0.5 meter depth; velocity found from—		At 3 meters depth; velocity found from 100 revolutions.	At 6 meters depth; velocity found from 100 revolutions.	Variation $\left(\frac{V_m - V}{V_m}\right)$.[a]		
100 revolutions.	500 revolutions.			At 0.5 meter depth.	At 3 meters depth.	At 6 meters depth.
Met. per sec.	*Met. per sec.*	*Met. per sec.*	*Met. per sec.*	*Per cent.*	*Per cent.*	*Per cent.*
1.909	1.877	1.861	1.111	−1.8	+6.6	3.6
1.942	1.846	2.030	1.069	−3.6	−1.9	+0.3
1.987	1.846	1.942	0.977	−6.0	+2.6	+8.9
1.942	1.846	2.030	1.180	−3.6	−1.9	10.1
1.861	1.832	2.030	1.044	+0.7	−1.9	+2.6
1.861	1.832	2.060	0.937	+0.7	−3.4	+12.6
1.887	1.823	1.909	1.021	−0.7	+4.2	+1.8
1.861	1.787	1.909	0.998	+0.7	+4.2	+7.0
1.861	1.809	1.861	0.977	+0.7	+6.7	+8.9
1.861	1.787	2.030	1.094	+0.7	−1.9	2.1
1.942	1.861	2.125	0.900	3.6	−6.7	+16.1
1.760	1.823	2.030	1.094	+6.1	−1.9	2.1
1.831	----------	2.086	1.021	+2.4	−4.7	+4.7
1.719	----------	1.994	1.180	+8.3	0.0	10.1
1.942	----------	2.086	1.079	3.6	−4.7	−0.7
1.831	----------	1.909	1.472	+2.4	+4.2	−37.4
1.875		1.993	1.072			

[a] V=velocity, V_m=mean velocity.

It is seen that during the period required for the meter to make 1,600 revolutions the greatest variations from the mean velocity at 0.5 meter depth are +8.3 per cent and −6 per cent and at 6 meters depth +16.1 per cent and −37.4 per cent. The greatest difference in velocity, as shown by two consecutive 100-revolution periods, is 12 per cent at 0.5 meter depth and 36.7 per cent at 6 meters depth. A velocity measurement of 100 revolutions 0.5 meter below the surface may be in error 8 per cent and one 6 meters below may be in error 37 per cent.

D. F. Henry[a] has observed this fluctuation in velocity at a given point in large and in small streams. He says: "The lesser fluctuations have a duration of 30 to 60 seconds and the larger ones from 5 to 10 minutes. They do not seem to be synchronous with the surface fluctuations, and are smaller at the surface than at the bottom."

Harlacher[b] found the velocity near the surface of the Rhine to vary 20 per cent in a few seconds, and near the bottom he found it to vary 50 per cent in the same period.

Marr's simultaneous observations of velocity in the Mississippi River at Burlington, Iowa,[c] with five current meters are described on page 48. The following table gives the velocity, as shown by two of his current meters, one near the surface and the other near the bottom, for consecutive periods of one minute each. The depth in

[a] Jour. Franklin Inst., Vol. LXII, p. 323.
[b] Trans. Am. Soc. Civ. Eng., Vol. XII, p. 311.
[c] Report on Current Meter Observations, Burlington, Iowa, by Maj. A. McKenzie, 1884.

the first section is 11 feet, in the second section 27.6 feet, and the meter is 4 feet above the bottom:

Variation in velocity per minute in Mississippi River at Burlington, Iowa.

Simultaneous observations in section No. 1.				Simultaneous observations in section No. 2.			
Velocity 1 foot below surface (V).	Variation $\left(\frac{V_m-V}{V_m}\right)$.	Velocity 9.1 feet below surface (V_m).	Variation $\left(\frac{V_m-V}{V_m}\right)$.	Velocity 3.6 feet below surface (V).	Variation $\left(\frac{V_m-V}{V_m}\right)$.	Velocity 23.6 feet below surface (V_m).	Variation $\left(\frac{V_m-V}{V_m}\right)$.
Ft. per sec.	*Per cent.*	*Ft. per sec.*	*Per cent.*	*Ft. per sec.*	*Per cent.*	*Ft. per sec.*	*Per cent.*
2.242	+2.0	1.724	0.0	2.286	+4.8	1.966	+ 2.4
2.267	+0.9	1.675	+ 2.9	2.353	+1.3	1.817	+ 9.8
2.252	+1.1	1.761	− 2.2	2.437	−2.3	1.985	+ 1.5
2.236	+2.2	1.744	− 1.2	2.300	+3.5	2.008	+ 0.3
2.267	+0.9	1.797	− 4.3	2.404	−0.9	2.065	− 2.5
2.299	−0.5	1.766	− 2.4	2.378	+0.2	2.119	− 5.2
2.289	0.0	1.772	− 2.8	2.414	−1.3	1.926	+ 4.4
2.274	+0.6	1.819	− 5.5	2.392	−0.4	2.008	+ 0.3
2.211	+3.3	1.712	+ 0.7	2.313	+3.0	1.983	+ 1.5
2.224	+2.8	1.644	+ 4.7	2.296	+3.8	2.081	− 3.3
2.280	+0.3	1.698	+ 1.5	2.383	0.0	2.104	− 4.5
2.239	+2.1	1.915	−11.1	2.397	−0.6	2.276	−13.3
2.280	+0.3	1.670	+ 3.1	2.420	−1.6	2.092	− 3.9
2.289	0.0	1.775	− 3.1	2.361	+0.9	2.008	+ 0.3
2.321	−1.5	1.582	+ 8.3	2.278	+4.4	2.047	− 1.6
2.420	−6.0	1.664	+ 3.5	2.445	−2.6	1.848	+ 8.3
2.445	−6.9	1.741	− 1.0	2.459	−3.2	2.024	− 1.0
2.308	−0.9	1.717	+ 0.5	2.428	−1.9	2.070	− 2.8
2.333	−2.0	1.800	− 4.4	2.456	−3.1	1.796	+10.8
2.264	+1.0	1.695	+ 1.7	2.460	−3.2	2.055	− 2.4
2.327	−1.3	1.812	− 5.1	----------	----------	----------	----------
2.311	−1.0	1.689	+ 2.0	----------	----------	----------	----------
2.305	−0.8	1.792	− 4.0	----------	----------	----------	----------
2.311	−1.0	1.627	+ 5.7	----------	----------	----------	----------
2.277	+0.4	1.554	+ 9.9	----------	----------	----------	----------
2.274	+0.6	1.678	+ 2.7	----------	----------	----------	----------
2.292	−0.2	1.731	− 0.4	----------	----------	----------	----------
2.271	+0.7	1.704	+ 1.1	----------	----------	----------	----------
2.321	−1.5	1.698	+ 1.5	----------	----------	----------	----------
2.261	+1.1	1.723	0.0	----------	----------	----------	----------
2.217	+3.6	1.757	− 1.9	----------	----------	----------	----------
2.280	+0.3	1.743	− 1.1	----------	----------	----------	----------
2.287	----------	1.724	----------	2.383	----------	2.014	----------

It is seen that in the first section the greatest departures of velocity from the mean are +3.6 per cent and −6.9 per cent at 1 foot below the surface, and +9.9 per cent and −11.1 per cent at 9.1 feet below the surface, or 2 feet above the bottom. The greatest difference in velocity obtained from two consecutive 1-minute periods is 6 per cent at 1 foot below the surface and 12.5 per cent at 9.1 feet below the surface, or 2 feet above the bottom. In the second section the greatest departures of velocities from the mean are +4.8 per cent and −3.2 per cent at 3.6 feet below the surface, and +10.8 per cent and −13.3 per cent at 23.6 feet below the surface, or 4 feet above the bottom. The greatest difference in velocity obtained from two consecutive 1-minute periods is 7 per cent at 3.6 feet below the surface and 13.6 per cent at 4 feet above the bottom. In the first section a velocity measurement near the surface may be in error 7 per cent and a measurement 2 feet above the bottom may be in error 11 per cent. In the second section a velocity measurement 3.6 feet below the surface may be in error 4.8 per cent and a measurement 4 feet above the bottom in error 13.3 per cent.

In 1899, while measuring the discharge of the St. Clair River, Mr. L. C. Sabin, assistant engineer, made some experiments to determine the pulsations or fluctuations in the velocity of the river at the discharge station. Four meters were used, placed 50 feet apart and at the same depth. In the first series of observations the meters were in a line across the river and at right angles to the current; in the second series they were in a line with the axis of the current. Simultaneous readings of the four meters were taken every fifteen seconds for several periods of ten minutes each. The results were plotted, using time as abscissæ and velocity as ordinates, and a curve drawn for each meter, showing the fluctuations in velocity in each fifteen seconds of time at four points 50 feet apart. These curves have two sets of waves—small ones of fifteen to sixty seconds amplitude and larger ones of three to six or more minutes amplitude. The range of velocity as found from the large waves is in some cases 35 per cent of the mean velocity shown by the meter for ten minutes. The curves for two adjacent meters are at times nearly parallel, but they soon diverge and cross each other occasionally. The curves for the meters in a line with the axis of the river resemble one another more closely and are more nearly parallel than those of the meters in a line across the river. These experiments indicate that the pulsations are very limited in extent in a direction at right angles to the current, but that they can be traced for some distance in the direction of the thread of the current. The whole depth of the river is affected by them, and their effect decreases from the bottom toward the surface.

The practical lesson to be drawn from the experiments by Sabin and others is that velocity observations of short duration are of little value unless they are numerous and well distributed over the discharge area. In order to eliminate the effect of the pulsations, each observation should extend over a period of from six to ten minutes. Long single observations and rapid fluctuations of water surface elevation require that discharge be found from single observations in comparatively few verticals, and that the ratio of velocity at this depth to mean velocity be known from vertical velocity curves. This emphasizes the need of a thorough investigation of the relation between velocity and depth in a vertical longitudinal plane and the change in this relation with change of river stage.

METHODS OF MEASURING AND COMPUTING STREAM FLOW.

WEIRS.

The discharge of a stream can be obtained by causing it to flow over a weir or dam the coefficient of which is known, by the substitution of observed data in a weir formula. Three sharp-crested or standard weir formulæ are in use, viz, Francis's, Fteley and Stearns's, and Bazin's. They differ much in form, and each is derived from experiments on small weirs with low heads. A brief discussion of

each formula is here given because of its bearing on the accuracy of discharge measurements. Bazin has determined the values of the coefficient of discharge over weirs of many other shapes of crest, and the Cornell University experiments of the Board of Engineers on Deep Waterways have extended the values of the coefficients of a few of these to the higher heads. Time and space, however, will not permit more than the mention of them here.[a]

The weir is the most accurate method of measuring discharge yet used for small streams if the coefficient of the weir be accurately known. The head on the weir and the velocity of approach are the only variables, and these can easily and accurately be measured. The disadvantages are (1) the cost of constructing a weir, or the difficulty of finding one in use whose shape closely resembles one whose coefficient is known, and (2) the limited range of values of the coefficient of a weir of any shape and the limited number of shapes that have been investigated.

FRANCIS'S EXPERIMENTS AND FORMULA.

In 1852 J. B. Francis made numerous very careful measurements of the volume of water passing over small weirs and the corresponding heads at Lowell, Mass.[b] His measuring tank was a canal lock which had a capacity of 12,138 cubic feet for a depth of 9.5 feet; the greatest length of crest was 10 feet; the head on the weir varied from 5 to 19 inches, and was measured with two hook gages 6 feet upstream from the crest; the width of the channel was about 14 feet. His formula, derived from these experiments, is as follows:

$$Q=\tfrac{2}{3}\times 0.622\, h_2(b-\tfrac{1}{10}\, nh_2)\sqrt{2\, gh_2}=3.33(b-\tfrac{1}{10}\, nh_2)h_2^{\frac{3}{2}}$$

Q=discharge in cubic feet per second; h=head on weir, or difference in elevation of weir crest and water surface; n is a constant whose value is 0 when both ends of the weir are flush with the sides of the channel, 1 when one side only is flush, and 2 when neither side is flush; g=acceleration of gravity. (See fig. 9.) The head on the weir should be not less than 0.5 foot nor more than 2 feet, the depth of water in the canal should be at least three times the head on the weir, and the air should have free entrance under the sheet. The velocity of approach of the water to the weir must be

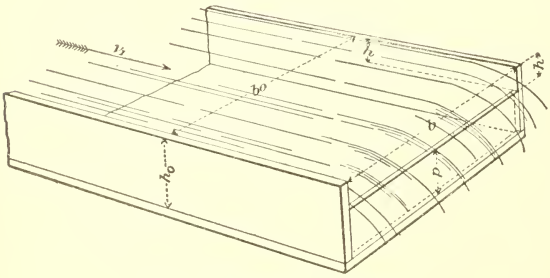

FIG. 9.—Sharp-crested weir.

[a] A discussion of these experiments, which were conducted by George W. Rafter, will be found in Trans. Am. Soc. Civ. Eng., Vol. XLIV, pp. 220-398.

[b] Lowell Hydraulic Experiments, by J. B. Francis, p. 133.

measured and the head corrected for it. The formula for this purpose is $h_2=[(h+h_1)^{\frac{3}{2}}-h_1^{\frac{3}{2}}]^{\frac{2}{3}}$, h being the measured head, h_1 the head due to the velocity of approach $=\frac{V_1^2}{2g}$ and $V_1=\frac{Q}{b_0h_0}$. (See fig. 9.)

Hamilton Smith, jr., says of this formula:[a] "It stands in the first rank in reliability."

Francis made eighty-eight experiments with two weirs of 10 and 8 feet length, in addition to those to derive his formula, and found that the greatest percentage difference between his measured discharge and the discharge computed by his formula was 0.9 per cent for the mean of two experiments and 0.68 per cent for the mean of eight experiments; for the other eleven means the difference is less than 0.4 per cent.

FTELEY AND STEARNS'S EXPERIMENTS AND FORMULA.

In 1877 and 1879 Fteley and Stearns[b] measured the discharge over weirs of 5 and 19 feet crest length and the corresponding head on weir, from which they derived the following formula for a standard weir with end contractions suppressed:

$$Q=3.31b\left[h+1.5\frac{V_1^2}{2g}\right]^{\frac{3}{2}}-0.007b.$$

Q=discharge in cubic feet per second, b=length of crest, h=head on weir, V_1=velocity of approach in feet per second. (See fig. 9.) Their measuring tank was a section of the Sudbury conduit having a capacity of 300,000 cubic feet for an increase in depth of 3 feet. The head on the weir was measured with a hook gage 6 feet upstream from the crest. The term $1.5\frac{V_1^2}{2g}$ corrects for velocity of approach. The head on the weir must be not less than 0.06 foot, and the air must have free access under the sheet. This formula is not used as generally as is that of Francis or Bazin. It was used by Fteley and Stearns to compute the discharge of the weir used in their current-meter and weir comparisons. (See p. 57.)

BAZIN'S FORMULA.

In 1886 and 1887 Bazin[c] made numerous measurements of the volume passing over weirs having lengths of from 0.5 meter to 2 meters and the corresponding heads. From these he derived the following formula for a standard weir with end contractions suppressed:

$$Q=\tfrac{2}{3}\mu\left[1+0.55\left(\frac{h}{p+h}\right)^2\right]bh\sqrt{2gh}$$

$$\text{and } \mu=0.6075+\frac{0.0148}{h\ \text{(in feet)}}.$$

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[a] Hydraulics, by Hamilton Smith, p. 93.
[b] Trans. Am. Soc. Civ. Eng., Vol. XII, p. 1.
[c] Annales des ponts et chaussées, 1888, p. 416.

This formula is true for any system of units (feet or meters). Q=discharge, b=length of crest, h=head on weir, p=distance of crest above bottom. (See fig. 9.) This formula needs no correction for velocity of approach. The measuring tank was a section of a rectangular channel 200 meters long, 2 meters wide, and 1.2 meters deep. The head on the weir varied from 0.05 meter to 0.6 meter. The air had free access under the sheet. Each of these formulæ will give the discharge to within about 1 per cent if the conditions existing when the observations on which the formula is based are exactly duplicated. Discharges computed from any two of these formulæ may differ 3 per cent.

CURRENT METERS.

If the stream be small, meter measurements are made from a bridge, if one can be found in a suitable location. Bridge piers, however,

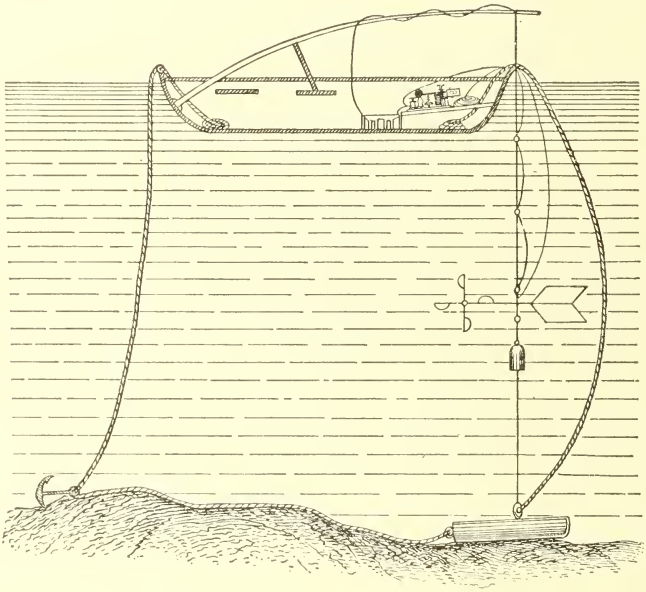

FIG. 10.—Method of using current meter on large river.

disturb the natural flow of a stream, as well as distort the vertical and transverse velocity curves and render them of only local application. Discharge measurements made where there are piers in the channel are, as a rule, less accurate than measurements made where there are no piers to obstruct the flow.

In case there is not a bridge at the desired place, the observer wades, if the water be shallow, taking observations of depth and velocity at as many points in the cross section as desired. If the water be deep and swift a cable is stretched across the stream at a convenient height above the water, and a car or box is suspended from it. From

this car, which is moved back and forth across the stream by the observer in it, the depth and velocity of the water are measured. If the current be not swift a surveyor's chain or a cable can be stretched across the stream temporarily and the depth and velocity be measured from a rowboat at points marked on the chain or cable.

In a large river like the Mississippi, where a steamboat can conven-

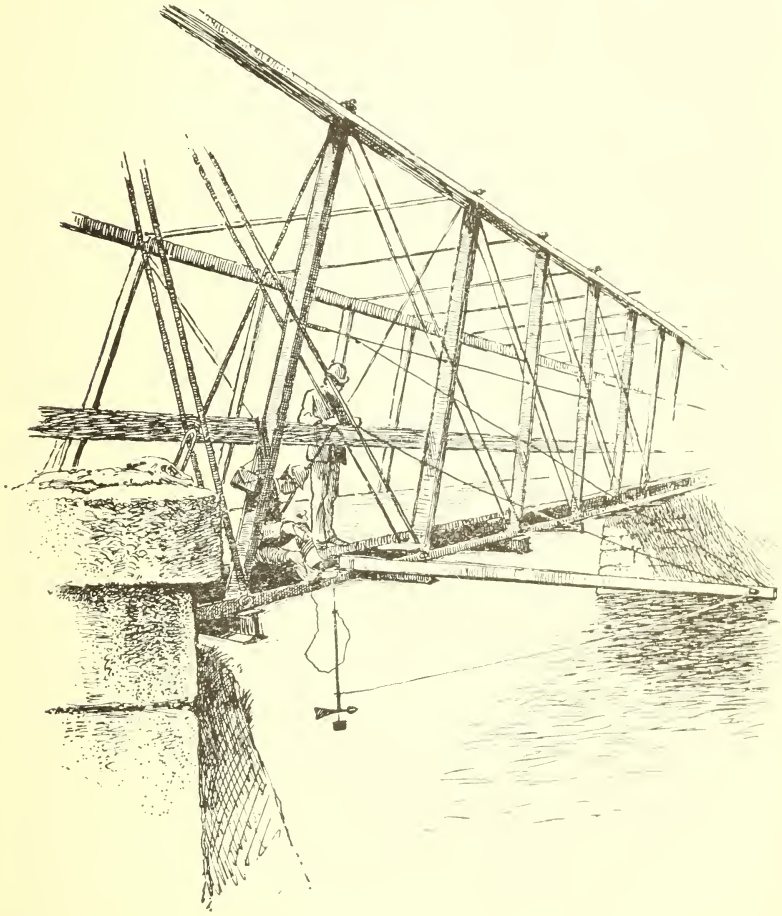

FIG. 11.—Device for holding meter in place.

iently anchor, a method that has been used satisfactorily is shown in fig. 10.[a] The boat is anchored in the proper place, and a lead weight of 50 pounds connected to the anchor is lowered over the stern. A copper wire is connected to this weight and to the spring pole in the boat, and the meter is moved up and down on this wire by a rope. The revolutions of the meter are recorded electrically in the boat, the cop-

[a] Jour. Franklin Inst., Vol. LXII, p. 171.

per wire being connected to one pole of the battery and an insulated wire connected to the meter and the other pole.

On large rivers where boats can not anchor the measurements are made from a boat towed by a steamboat.[a] The meter is kept in position by two lines of range poles at right angles to each other. The pilot on the steamboat steers it so as to keep it in line with one range, while the engineer, with his hand on the steam valve and his eye on the other range, controls the speed of the boat so that it will remain in a fixed position.

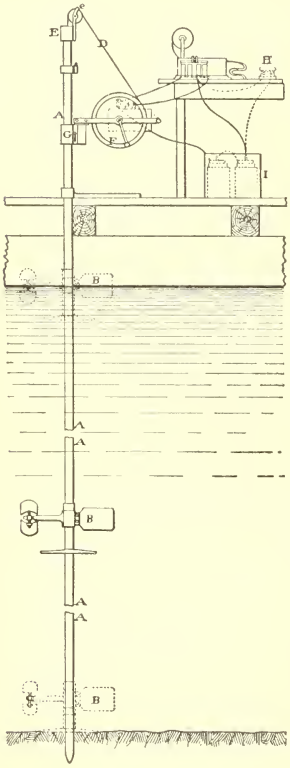

FIG. 12.—Harlacher's apparatus for moving a meter with uniform velocity.

In a swift current the meter and its sinker will be carried downstream a distance depending on the weight of the sinker and the depth and velocity of the water. There are two methods of treating this difficulty. One is to apply a special device like that shown in fig. 11 to keep the meter in place;[b] the other is to compute from the weight of the sinker and the depth and approximate velocity of the water the additional length of cable to use in order that the meter may sink to the required depth.[c] The first is the better for streams of ordinary size. In the device shown in fig. 11 the stay line is attached to the meter and is passed over a pulley at the end of the stay pole, being held by an assistant. By means of this stay line and the vertical cord the meter can be kept nearly in position. Instead of a stay pole a wire cable is sometimes used to keep the stay line in place.

POINT AND INTEGRATION METHODS.

There are two methods of using a meter in a cross section, as follows: (1) The point method, in which the meter is held at certain points in the cross section for a stated period of time, usually fifty seconds, and the number of revolutions of the wheel of the meter during that time are observed, either by counting the clicks of a buzzer or reading a register; and (2) the integration method, in which, instead of holding the meter at certain points, it is moved with a uniform speed through the section, the time and number of revolutions being observed as before. The point method is the more accurate if sufficient observations are taken in the section. The velocity found by the integration method is the resultant of

[a] Jour. West. Soc. Eng., Vol. III, No. 3.
[b] Twentieth Ann. Rept. U. S. Geol. Survey, Pt. IV, p. 20.
[c] Jour. West. Soc. Eng., Vol. IV, No. 6.

the velocity of the water and that of the meter as it is carried by the observer, and must always be greater than the true velocity. The error increases with the speed of the meter, and also increases as the velocity of the water decreases. When the point method is used the meter may be held at several points in certain verticals, in which case we will call it the ordinary method; or it may be held

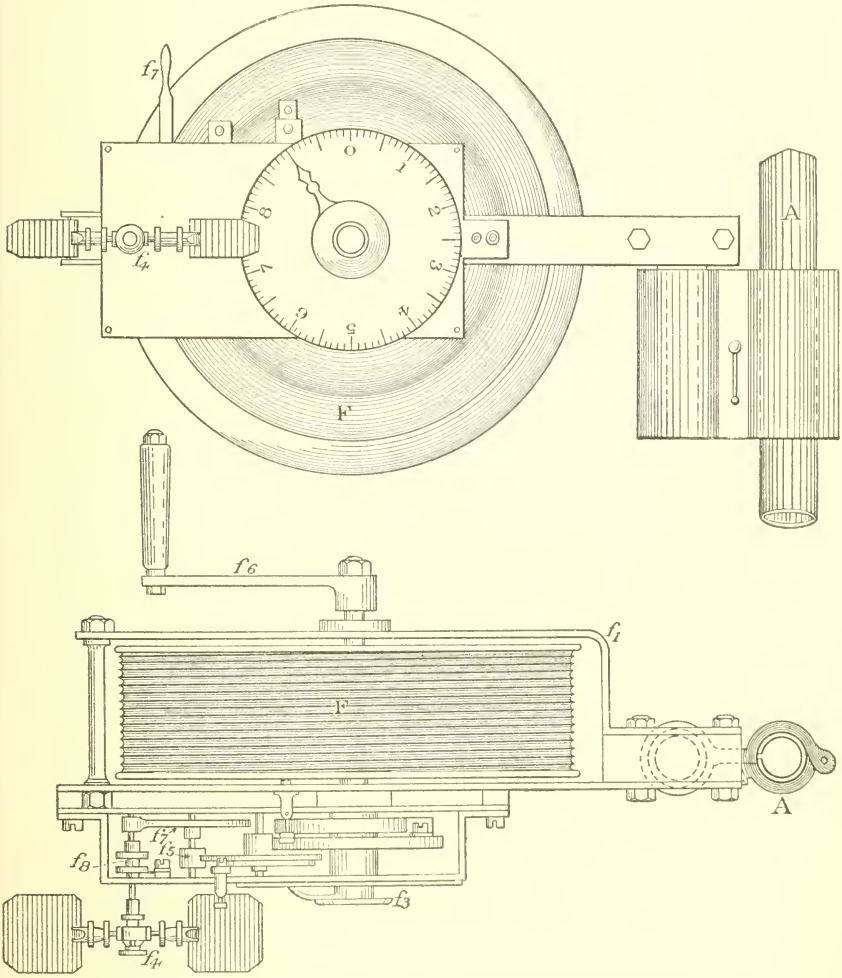

FIG. 13.—Details of Harlacher's apparatus for moving a meter with uniform velocity.

at the surface, at mid depth, and at the bottom in certain verticals, and the discharge be found from these (see Moore's method, p. 45); or it may be held at the surface and the bottom only in several verticals, and the mean velocity be found from these; or it may be held at three-tenths, at six-tenths, or at mid depth in certain verticals, and the mean velocity be found by applying a factor. The

three-tenths-depth point[a] is used because it is said to be the point of maximum velocity in a vertical, and a small error in the position of this point will not affect the result much. The mid-depth point[b] is employed because the factor which is used to obtain the mean velocity is more nearly constant for it than for any other point on a vertical curve. The six-tenths-depth point[c] is used because it is believed to be the depth of the thread of mean velocity.

In the integration method the meter may be moved down several times in certain verticals only, as used by Harlacher,[d] or across the stream at a given depth, as used by Price on the Mississippi River at Carrollton, La.,[e] or diagonally across from one side to the other at the same time that it is moved from the surface to the bottom several times, as used by the writer and others. Harlacher's apparatus for moving a meter with a uniform velocity is shown in figs. 12 and 13. The meter B is moved up or down on the iron tube AA by the rope D attached to the drum F. E is a bracket holding the pulley e. G is an arm supporting the drum F, and f_3 (fig. 13) is a dial on which is registered the depth. The fan f_4 (fig. 13) and the gearing f_5 regulate the rate of motion of the meter; f_6 is a crank lever for raising the meter, and f_8 a ratchet wheel for arresting the motion. I (fig. 12) is an electric battery, and H (fig. 12) is the registering apparatus.

When accurate results are desired the meter should be held with a rod, if the depth be not too great, in which case it is not free to turn sidewise, but keeps its axis parallel to the axis of the stream and can be placed close to the bottom. Ordinarily it is held with an insulated wire, and is free to take the direction of the water at the point where it is held.

COEFFICIENT WORK.

Coefficient work in river gaging consists of obtaining the ratio of the velocity at any point in the depth of the stream (called the index point), as, for example, the three-tenths-depth point, to the mean velocity in the whole depth. When this ratio or coefficient is known for a vertical, the mean velocity in that vertical can be found by making an observation at the index point and applying the coefficient.

Let C_1, C_2, C_3, etc., be the coefficients for the component parts, F_1, F_2, F_3, etc., of the discharge area F; V_1, V_2, V_3, etc., the observed velocities at the index points of these areas; and V the mean velocity for the whole discharge area. The discharge $Q = FV = C_1F_1V_1 + C_2F_2V_2 + C_3F_3V_3 + \ldots\ldots$ (1).

A value of each of these coefficients can be found for each foot variation of river stage. The discharge of the stream is then computed by equation (1) from observed values of V_1, V_2, V_3, etc., at the

[a] Jour. West. Soc. Eng., Vol. III, No. 3.
[b] Report on Current Meter Observations, Burlington, Iowa, by Maj. A. McKenzie, 1884.
[c] Proc. Inst. Civ. Eng., Vol. LXXI, p. 60.
[d] Ibid., Vol. LXVII, p. 358.
[e] Jour. West. Soc. Eng., Vol. III, No. 3.

index points, using the set of values of the coefficients which correspond with the observed river stage.

Coefficient work can be done with one current meter, but it can be done more rapidly with two or more meters. When two meters are used, one is placed at the index point and the other is held for several minutes at as many points in the vertical as desired, and simultaneous readings of the two meters are obtained at each point. The two meters are occasionally held at the same depth and relative readings of the meters are obtained. A chart can be prepared from the ratings of the meters in still water which will give the velocity ratio from the simultaneous readings of the two meters. For example: The index meter at three-tenths depth indicates 2.34 revolutions per second. The other meter, at eight-tenths depth, indicates 2.05 revolutions per second. The chart shows the velocity ratio for these meter speeds to be 0.89. From the velocity ratio at each tenth of the depth the ratio of the mean velocity in the vertical to the index velocity, or C, is found.

This coefficient method of gaging is better and more accurate for large streams than the slower one in which velocity observations are made at several points in each vertical, on account of the rapid changes of surface elevation of the stream.

RATING OF METERS AND CONSTRUCTION OF RATING TABLES.

The accuracy of a discharge measurement depends largely on the accuracy of rating the meter used. Errors of observation are as likely to be too large as too small, and are compensating. Errors in a rating table always have the same sign and are cumulative, hence they should be eliminated or reduced to a minimum.

There are two kinds of rating of a current meter, absolute and relative. From the former the absolute velocity at a single point is found; from the latter the ratio or coefficient of velocity at any two points is found. The former is usually employed in still water, the latter in running water.

Four methods have been used for rating meters: (1) By the use of surface floats; (2) by moving the meter through still water with a known velocity; (3) by observing velocity at many points in a cross section and comparing this with the known mean velocity; and (4) by attaching the instrument to a long arm and revolving it about a vertical axis in a body of still water. The second method is the one now universally used. The meter is suspended from a car or a boat and is moved with a uniform velocity through still water at a depth of 2 or more feet below the surface. The length of a run varies from 100 to 300 feet, with a starting run sufficient to allow the meter wheel to reach the proper speed before entering the run. It is moved across and back over the run to eliminate the effect of velocity in either direction. The rating equipment should be such as to give time of

run to the tenth of a second and speed of meter to the tenth of a revolution (a chronograph recording time, revolutions, and the instants of beginning and ending the run should meet this requirement).

The range of velocities employed in rating should be those for which the meter is to be used. If it is to be employed mainly to measure low velocities the speeds in rating should be low. The rating table should not be extended beyond the limits of velocity used in the rating.

The relation between distance passed over by the meter and the corresponding revolutions of the meter wheel is often assumed to be a straight line. It is always a curved line, and must be so on account of friction of bearings and inertia of moving wheel. A velocity of from 0.1 to 0.5 foot per second is necessary to start the wheel. As the velocity increases the effect of friction and inertia becomes proportionately less and the curve approaches a straight line. The relation between velocity and revolutions of wheel per second is of the second degree and concave to the axis of velocity. For velocities of 2 or more feet per second this curve differs little from a straight line.

The results of the rating are usually plotted on squared paper, using revolutions per second as ordinates and velocity as abscissæ, and all observations that fall much from a well-defined line are rejected. If this line be nearly straight between the limits of the observed revolutions its equation is assumed to be of the form $y=a+bx$, y being velocity, x revolutions per second, and a and b constants. If the results indicate a curved line its equation is assumed to be of the form $y=a+bx+cx^2$. There are two methods of preparing the rating table from the observations. The first method is rapid. The most probable curve is drawn among the plotted observations, and the velocities to tenths of a revolution are read from the curve. In the second method the equation of the most probable relation is derived by the method of "least squares" and then the table is prepared from the equation. The writer has found it better to plot values of x and the ratio y to x (see fig. 29, p. 89) instead of x and y. The reason is that the ratio y to x changes rapidly as x increases and can be read more accurately from this curve than from a nearly straight line. It can be shown mathematically that these curves are approximately branches of hyperbolas.

The second method, which is to derive the equation of the most probable relation between velocity and revolutions by the method of "least squares," first rejecting the observations that fall much outside of a well-defined curve, is the most accurate, but it requires the most time. If the meter is to measure low velocities to within 1 per cent, the second method must be used. It gives n observation equations of the form $y-a+bx=v$ if the relation be linear, or $y-a-bx-cx^2=v$ if it be a parabolic curve. v is a small quantity called a residual, or a residual error. Its value would be zero if the observations were perfect. According to the principle of least squares, the best values

of the constants are those that make the sum of the squares of the residuals a minimum.

Squaring each of these n equations and adding, we have

$$\Sigma v^2 = v_1^2 + v_2^2 + v_3^2 + \ldots = [y' - a - bx' - cx'^2]^2 + [y'' - a - bx'' - cx''^2]^2 + [y''' - a - bx''' + cx'''^2]^2 + \ldots$$

Taking the first derivative of this equation with respect to a, b, and c and placing these equal to 0, we have

$$d\frac{(\Sigma v^2)}{da} = -2\,[y' - a - bx' - cx'^2] - 2\,[y'' - a - bx'' - cx''^2] \ldots = 0$$

$$d\frac{\Sigma v^2}{db} = -2x'\,[y' - a - bx' - cx'^2] - 2x''\,[y'' - a - bx'' - cx''^2] \ldots = 0$$

$$d\frac{\Sigma v^2}{dc} = -2x'^2\,[y' - a - bx' - cx'^2] - 2x''^2\,[y'' - a - bx'' - cx''^2] \ldots = 0$$

From these normal equations the values of a, b, and c can be found.

For the linear function these equations become two in number and have the form

$$a\Sigma x + b\Sigma x^2 = \Sigma xy$$
$$na + b\Sigma x = \Sigma y$$

and a and b are found from these equations.

This relation between revolutions per second and velocity, whatever it may be, is not constant. Below are given the ratings of a Price meter, obtained by J. C. Bailey, United States assistant engineer.[a]

Results of four ratings of a Price meter used in 1892 on Niagara River.

Date.	Number of observations.	Velocity.	Meter coefficients.		Remarks.
			a	b	
		Ft. per sec.			
April 28	20	2.5 to 7.3	4.239	+0	Still water; base 150 feet long.
April 29	34	2.1 to 6.7	4.256	+0.061	Do.
May 4	49	1.7 to 7.7	4.046	+0.207	Do.
May 17	43	2.0 to 8.0	4.130	+0.067	Still water; base 300 feet long.
			4.168	+0.0848	

Values computed from two ratings of current meter on April 29 and May 4, 1892.

[April 29, $V_1 = 4.256\,R + 0.061$; May 4, $V_2 = 4.046\,R + 0.207$.]

R	V_1	V_2	$V_2 - V_1$	$\frac{V_2 - V_1}{V_2}$
0.05	0.274	0.409	0.135	0.314
0.10	0.487	0.612	0.125	0.204
0.15	0.699	0.814	0.115	0.141
0.20	0.912	1.016	0.104	0.102
0.25	1.125	1.219	0.094	0.077
0.30	1.338	1.421	0.083	0.058
0.35	1.551	1.623	0.072	0.044
0.40	1.763	1.825	0.062	0.034
0.45	1.967	2.028	0.052	0.026
0.50	2.189	2.230	0.041	0.018

[a] Engineering News, Vol. XXIX, 1893.

The foregoing table shows that if on May 4 velocity measurements had been made from 0.05 to 0.50 revolution per second and the rating table of April 29 had been used the results would be in error from 1.8 per cent to 31.4 per cent. It is true that neither set of values of a and b was determined for low velocities. This, however, emphasizes the fact that values of a and b found for high velocities may be greatly in error for the low velocities if the linear relation is assumed. These four ratings of a meter in less than one month show considerable variation in the values of a and b, and indicate that when a meter is in constant use its rating should be examined once a week if accurate work is required.

A rating table that gives velocity to only two places of decimals is not sufficiently accurate for low velocities. To illustrate this we will take the case of the rating table of small Price meter No. 363, rated at Chevy Chase, Md., June 26, 1900. The velocity corresponding with 0.05 revolution per second is given as 0.17 foot per second. This may mean any value from 0.166 foot per second to 0.174 foot per second. This is 2.04 per cent of 0.17. Hence if the computed revolutions were either 0.166 or 0.174 the error introduced by using this rating table would be 2.4 per cent. The following table shows the error for other velocities given in this rating table. If the velocity be 0.25 foot per second it may be in error nearly 2 per cent if found from this table.

Table showing greatest percentage error in rating table of small Price meter No. 363, which gives velocity to only two places of decimals.

Revolutions per second.	Velocity.	Error $\frac{0.004}{V}$.	Revolutions per second.	Velocity.	Error $\frac{0.004}{V}$.
	Ft. per sec.	*Per cent.*		*Ft. per sec.*	*Per cent.*
0	0.06	6.7	0.25	0.63	0.6
0.05	0.17	2.4	0.30	0.75	0.5
0.10	0.29	1.4	0.35	0.86	0.5
0.15	0.40	1.0	0.40	0.98	0.4
0.20	0.52	0.8	0.45	1.09	0.4

Darcy and Bazin employed the first three methods to rate the Pitot tube which they used in their hydraulic investigations on canals.[a] Fig. 2, page 19, shows this instrument as they used it. A discussion of the results of the ratings is given here on account of the light they throw on accuracy tests.

[a] Recherches hydrauliques, by Darcy and Bazin, 1865, pp. 63–70.

Results of Pitot tube ratings by Darcy and Bazin.

First method.[a]			Second method.[b]			Third method.[c]					
No. of experiment.	Value of coefficient.	Number of experiments.	Velocity of boat.	Value of coefficient.	Number of experiments.	Designation of experiment. Series.	Designation of experiment. No.	Value of coefficient.	Mean Velocity.	Channel. Shape.	Channel. Width.
			Meters.						*Meters.*		*Meters.*
2	0.987	8	0.609	1.040	2	51	1	1.021	0.508	[d]	0.8
3	1.024	8	0.692	1.053	1	51	2	1.010	0.768	[d]	0.8
4	0.981	8	0.785	1.032	3	51	3	1.018	1.028	[d]	0.8
5	1.013	8	0.938	1.033	1	52	1	1.029	0.376	[d]	0.48
6	1.006	8	0.980	1.040	3	52	2	1.000	0.542	[d]	0.48
7	0.988	8	1.120	1.015	1	52	3	1.006	0.694	[d]	0.48
8	1.012	8	1.231	1.028	1	58	4	1.005	1.429	[d]	1.994
9	1.008	4	1.333	1.032	1	59	4	0.969	2.318	[d]	1.994
10	1.008	4	1.385	1.048	1	60	2	0.968	2.571	[d]	1.994
11	1.009	4	1.470	1.029	1	61	4	0.966	1.267	[e]	1.994
12	1.007	4	1.500	1.040	1	62	4	0.965	1.979	[e]	1.994
13	1.015	4	1.611	1.033	2	63	3	0.988	2.199	[e]	1.994
14	1.039	4	1.661	1.027	1	64	1	0.996	0.856	[e]	1.994
15	0.994	4	1.775	1.042	1	64	2	0.988	0.948	[e]	1.994
16	1.007	4	1.819	1.031	3	65	4	0.978	1.511	[e]	1.994
17	1.023	4	1.863	1.027	3	66	1	1.015	1.464	[e]	1.994
.....	.....	.....	1.930	1.039	1	66	2	0.984	1.675	[e]	1.994
.....	.....	.....	1.976	1.025	4	68	4	0.976	1.497	[f]	1.984
.....	.....	.....	2.034	1.037	1	71	6	0.968	1.810	[g]	1.40
.....	.....	.....	.....	.....	.....	72	5	1.017	1.679	[g]	1.40
.....	.....	.....	.....	.....	.....	73	4	0.967	1.612	[g]	1.40
.....	.....	.....	.....	.....	.....	74	4	1.014	1.229	[g]	1.40
.....	.....	.....	.....	.....	.....	84	2	1.014	1.033	[h]	1.990
.....	.....	.....	.....	.....	.....	84	3	0.984	1.246	[h]	1.990
.....	.....	.....	.....	.....	.....	85	1	0.998	1.011	[h]	1.990
.....	.....	.....	.....	.....	.....	85	2	0.997	1.218	[h]	1.990
.....	.....	.....	.....	.....	.....	85	3	0.990	1.473	[h]	1.990
.....	.....	.....	.....	.....	.....	88	1	0.995	0.894	[h]	1.990
.....	.....	.....	.....	.....	.....	88	2	0.986	0.921	[h]	1.990
.....	.....	.....	.....	.....	.....	88	3	0.980	0.955	[h]	1.990
.....	.....	.....	.....	.....	.....	88	4	0.993	1.010	[h]	1.990
	1.006			1.034				0.993			

[a] By surface floats.
[b] In still water.
[c] In moving water.
[d] Rectangular covered wooden channel.
[e] Rectangular open wooden channel covered with cloth.
[f] Trapezoidal open wooden channel covered with cloth.
[g] Semicircular.
[h] Rectangular.

In the first method the floats were run over a distance of 40 meters and the tube was held with its point 0.02 meter below the surface of the water. C is found from $v = C\sqrt{2g\frac{\Sigma d}{2}}$, v being known from the floats. In the second method the tube was fastened in front of a boat and was drawn through still water at different observed velocities. In the third method the instrument was held at many points in a cross section of an experiment canal 2 meters wide, the mean velocity in which was known, and the mean velocity as shown by the tube was computed.

It is seen that the three values of C found by these three methods differ somewhat, although each is the mean of many observations. The value found by the second method (the one now commonly used) is the largest of the three and is rejected on account of the action of the boat on the instrument. The pull on the boat as it was drawn through the water tipped the point of the tube down slightly, making

its indications less than they should be and making C too large. By the first method the mean of experiments Nos. 2 to 8 is 1.0016 and the mean of experiments Nos. 9 to 17 is 1.0122. The difference between these is nearly 1 per cent of the former. The greatest variations from the mean of all the observations by the first method are +1.8 per cent and −2.5 per cent. The value of C found by the third method is 0.993, obtained from thirty-one measurements of discharge of the experiment canal. The tube was held at many points in the cross section. The variations from this mean are +3.6 per cent and −2.8 per cent. Darcy uses the mean of the values found by the first and third methods, which makes $C=1$. The extreme variations from this mean are +3.9 per cent and −3.5 per cent. The velocity of the water during these ratings varied from 0.5 to 2.5 meters per second, or from 1.64 feet to 8.20 feet per second.

GENERAL FORMULÆ FOR COMPUTING DISCHARGE.

Whatever method is used in computing discharge, the depth must be known at a sufficient number of points in the cross section to determine the cross-sectional area with the required degree of accuracy. For a small stream it should be known at each foot of width, for large streams at each 5 or 10 feet of width.

The cross-sectional area (F) is found from the following formula:

$$F=\frac{b}{-}\left[d_1+4\left(d_2+d_4+d_6+d_{n-1}\right)+2\left(d_3+d_5+d_7+dn\right)+dn+1\right].$$

d_1, d_2, d_3, etc., being depths and b the distance between the points where the depths are measured.

The general formula for the discharge per second is

$$Q=F_1V_1+F_2V_2+F_3V_3+F_nV_n. \qquad (1)$$

F_1, F_2, F_3, etc., are the component parts of the cross section, and V_1, V_2, V_3, etc., the mean velocity in each of these parts. If the width of these component parts is b and the mean depth in each is d_1, d_2, d_3, this formula can be written

$$Q=b\left(V_1d_1+V_2d_2+V_3d_3+\text{——}\right). \qquad (2)$$

If $d_1=d_2=d_3$—, that is, if the channel is rectangular in cross section, then formula (2) becomes

$$Q=bd\left(V_1+V_2+V_3+\text{——}\right). \qquad (3)$$

The component velocities are found (1) from a single observation at some depth by applying a coefficient, as a mid-depth velocity observation multiplied by 0.95, or a six-tenths-depth observation multiplied by unity, and (2) from a vertical velocity curve. The latter, as already explained, is found from numerous observations at points in the depth, and the mean velocity in this vertical is then the area inclosed between the vertical curve and a vertical line representing no

velocity divided by the depth. Harlacher's method of integrating[a] in a vertical gives each component velocity very readily and quickly. Any component velocity is $\frac{RC}{T}$, R being the observed revolutions, T the observed time in seconds, and C the number, which changes from revolutions to velocity.

In measuring the discharge of a large river the component velocities are always found from an observation at some given depth and the use of a coefficient. As the depth or stage of a river is almost constantly changing, it is necessary to make the velocity observation in a short time—one or two hours at most. The value of the coefficient to use to reduce observed velocity at any depth to mean velocity in that vertical should be found from measurement if possible.

The discharge measurements of the Niagara River made in 1897 and 1898 by the United States Board of Engineers on Deep Waterways[b] from the international bridge 3 miles below the head of the river, were computed from velocity observations at three-tenths depth, using coefficients whose values were found from vertical velocity curves. The meter stations were about 80 feet apart and were at the middle of each half span of the short spans and at the middle of each one-third span of the long spans. The value of the coefficient for reducing observed velocity to mean velocity ranged from 0.61 to 1.17, being influenced by the piers of the bridge.

T. V. Moore in his discharge measurements of the Thames[c] assumed the vertical velocity curve to be a parabola, and computed its area from the formula $A=\frac{d}{6}[V_s+4V_m+V_b]$, d being the depth, V_s the surface velocity, V_m the velocity at mid depth, and V_b the bottom velocity. The discharge per second flowing between the end sections he computed from the formula $V=\frac{h}{3}[\Sigma A_1+4\Sigma A_2+2\Sigma A_3]$, h being the distance between the consecutive sections, ΣA_1 the sum of the two end sections, ΣA_2 the sum of the odd sections, and ΣA_3 the areas of the even sections. The discharge is found by adding to this the small volume flowing between each end section and the shore.

T. G. Ellis, in computing the discharge of the Connecticut River in 1874, multiplied the velocity at mid depth in each component area by 0.95 to find the mean velocity in that area.[d] In computing the discharge of the Mississippi River in 1882 the velocity at mid depth in each component area was multiplied by 0.91 for the observations taken when the river was covered with ice, and by 0.96 when free from ice, to reduce the mean velocity in a vertical.[e] From 1885 to 1887 the velocity at six-tenths depth was observed in the component areas, and this was taken as the mean velocity in each area.

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[a] Proc. Inst. Civ. Eng., Vol. LXVII, p. 358.
[b] Jour. West. Soc. Eng., Vol. IV, No. 6.
[c] Proc. Inst. Civ. Eng., Vol. XLV, p. 220.
[d] Trans. Am. Soc. Civ. Eng., Vol. IV, p. 303.
[e] Jour. West. Soc. Eng., Vol. III, No. 3.

Harlacher's method of computing flood discharge where the surface velocity only could be measured is illustrated in fig. 14.[a] The surface velocity was measured at a sufficient number of points (1, 2, 3, etc.) in the cross section ACB to determine the surface velocity curve ADB. The line ACB shows the depth at each point and is plotted from soundings taken immediately before or after the flood.

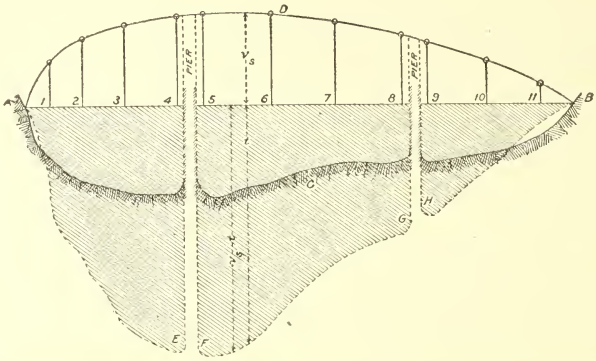


FIG. 14.—Diagram illustrating Harlacher's method of computing flood discharge.

The openings between EF and GH are bridge piers, the measurements being made from a bridge. The product of the surface velocity v_s and the corresponding depth t is found for a sufficient number of points, depending on the irregularity of the bottom and the curve $AEFGHB$ drawn. The discharge per second is the area between the line AB and the curve $AEFGHB$, less the piers, multiplied by 0.85.

COMPARISONS OF RESULTS WITH DIFFERENT INSTRUMENTS AND METHODS.

SURFACE FLOATS AND PITOT TUBE.

On page 43 we have given the results of three ratings of a Pitot tube by Darcy and Bazin.[b] In the first method the surface velocity was found from surface floats and a Pitot tube, as already described. Ninety-two experiments were made. The results are combined, according to velocity, into seven groups of eight experiments each and nine groups of four experiments each. The value of the coefficient as found from the first seven groups differs from that found from the mean of the last groups by about 1 per cent. The extreme variations of these individual means from the mean of all the experiments are − 1.8 per cent and + 2.5 per cent. The individual values of the coefficient are not given. Their extreme variation from the mean of all must be at least twice that of the individual means from the general mean.

[a] Proc. Inst. Civ. Eng., Vol. XCI, p. 399.

[b] Recherches hydrauliques, by Darcy and Bazin, 1865, pp. 63-70.

PITOT TUBE AND RECTANGULAR ORIFICES.

On page 43 are given the results of a third rating of a Pitot tube by Darcy and Bazin (third method). This is also a comparison of the discharge of a canal 2 meters wide, as found from rectangular orifices and as found from numerous velocity measurements in a cross section of the canal with the same Pitot tube. The discharge of the rectangular orifices admitting water to the canal was determined by experiment for different heads on them. The number of velocity measurements in each experiment or discharge measurement varied with the depth of the water in the canal, being from twenty-seven in the smallest channel, which was 0.30 meter by 0.48 meter, to ninety-one in the canal 2 meters wide. The points of measurement were nearest together where the velocity changed most rapidly. The results of thirty-one discharge measurements are given, the mean velocity varying from 0.38 meter to 2.57 meters per second. The extreme variations from the mean of all the values of the coefficient are + 3.6 per cent and — 2.8 per cent.

DOUBLE FLOATS AND CURRENT METER.

ELLIS'S EXPERIMENTS.

In 1874 T. G. Ellis made numerous velocity measurements of the Connecticut River at Thompsonville, Conn., with current meters and with double floats like that shown in fig 1.[a] Vertical velocity curves were obtained in planes parallel with the axis of the river and 100 feet apart, with the meters and with the floats. Each of these curves was plotted on cross-section paper and divided into tenths of the depth. All of the curves in which the mean velocity was less than 1.86 feet were combined by combining all the observations at each tenth of depth; all in which the mean velocity was more than 1.86 feet were combined in the same way. From the resultant vertical velocity curves the results in the following table are taken:

Comparison of velocity by double floats and current meters from measurements by T. G. Ellis on Connecticut River in 1874.

Observations.	Mean velocity, in feet per second, at various depths.											Mean.	Variation.
	Surface.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Bottom.		
													P. ct.
Meter below av. velocity 1.86	1.15	1.19	1.22	1.22	1.19	1.14	1.11	1.03	0.94	0.79	0.46	1.063	25.8
Float below av. velocity 1.86	1.50	1.52	1.52	1.53	1.49	1.46	1.35	1.29	1.20	0.97	0.58	1.337	
Meter above av velocity 1.86	2.96	3.08	3.12	3.06	2.99	2.91	2.78	2.62	2.42	2.16	1.47	2.735	5.7
Float above av. velocity 1.86	3.26	3.24	3.17	3.17	3 11	3.01	2.94	2.80	2.60	2.35	1.78	2.891	
All meter observations	2.05	2.12	2.15	2.13	2.08	2.01	1.93	1.81	1.67	1.47	0.96	1.887	12.0
All float observations	2.38	2.38	2.35	2.35	2.30	2.23	2.15	2.04	1.90	1.60	1.18	2.114	

[a] Rept. Chief Eng. U. S. A., 1878, Appendix B.

It is seen from the foregoing table that the velocity as found with the meter is from 6 to 26 per cent less than that found with the floats, and that the difference between the meter and float velocities increases as the velocity decreases.

Ellis gives also the following values of the ratio of mean velocity in a vertical (Vm) to mid-depth velocity in that vertical ($V_{\frac{1}{2}} D$) and the ratio of distance below the surface of mean velocity (m) to total depth (D).

Mean ratios from vertical velocity curves obtained by Ellis on Connecticut River in 1874.

Observations.	$Vm \div V_{\frac{1}{2}} D$	$m \div D$
Meter at low velocities	0.933	0.656
Floats at low velocities	0.918	0.622
Mean of low velocities	0.930	0.652
Meter at high velocities	0.939	0.628
Floats at high velocities	0.961	0.637
Mean of high velocities	0.944	0.629
Mean of meter measurements	0.937	0.638
Mean of float measurements	0.947	0.632
Mean of all measurements	0.940	0.636

From the foregoing table it is seen that $\frac{Vm}{V_{\frac{1}{2}} D}$ varies from about 0.92 to 0.96 and $\frac{m}{D}$ from 0.62 to 0.66—about the same range of values.

MARR'S EXPERIMENTS.

In October, 1879, G. A. Marr made simultaneous velocity measurements of the Mississippi River at Burlington, Iowa, with double floats like those shown in fig. 1 and with five current meters.[a] The river where measured was about 2,000 feet wide, and the path of the floats was near the center, where the depth was about 16.4 feet. Ten floats were run in succession in a period of about twenty-five minutes over a distance of 200 feet, and the time of entering and leaving each quarter of the run was recorded on a chronograph of eight pens. The five current meters were fastened to a cable held vertically 16 feet below the end of the run. One meter was at mid depth (the depth of the lower float), and the other four were arranged two above and two below it, so as to divide the depth into equal parts. One pen of the chronograph recorded the time of passage of each float, two recorded the time as shown by a chronometer, and the other five recorded the revolutions of the five meters. From a table giving the velocity of each float over each quarter of the run and the velocity shown by each of these meters during the time of passage over these distances the following table has been prepared:

[a] Report on Current Meter Observations, Burlington, Iowa, by Maj. A. McKenzie, 1884.

Comparison of velocity by double floats and current meters from measurements by G. A. Marr on Mississippi River at Burlington, Iowa, October, 1879.

Number of float.	Mean velocity found from 200-foot run.		Difference ($Vm-Vf$).	Mean velocity found from 50-foot run.		Difference ($Vm-Vf$).
	Float (Vf).	Meter (Vm).		Float (Vf).	Meter (Vm).	
	Ft. per sec.	*Ft. per sec.*	*Ft. per sec.*	*Ft. per sec.*	*Ft. per sec.*	*Ft. per sec.*
1	2.543	2.604	+0.061	2.660	2.597	−0.063
2	2.741	2.546	−0.195	2.976	2.657	−0.319
3	2.634	2.520	−0.114	2.674	2.630	−0.044
4	2.446	2.435	−0.011	2.456	2.481	+0.025
5	2.850	2.468	−0.382	2.847	2.590	−0.257
6	2.672	2.700	+0.028	2.778	2.649	−0.129
7	2.514	2.545	+0.031	2.674	2.484	−0.190
8	2.832	2.457	−0.375	2.857	2.749	−0.108
9	2.476	2.625	+0.149	2.569	2.821	+0.252
10	2.829	2.758	−0.071	3.012	2.823	−0.189
	2.654	2.566	.....	2.750	2.648	.....

In the foregoing observations the velocity of a float was not the same over each 50-foot length of the run. Each velocity given in the second column is a mean for the whole run of 200 feet, and the meter velocity in the third column is for the time of the full run. The velocity in the fifth column is for the fourth section of the run, and the corresponding number in that column is the meter velocity for the next consecutive and equal interval of time. The chief thing to be noticed is that the float velocity, whether computed from the whole run of 200 feet or from the shorter run of 50 feet, is greater than the meter velocity by about 3.5 per cent. We may note also that we have here forty mid-depth velocities in nearly the same vertical taken in about twenty-five minutes. For the ten found from the floats on the long run the variations of velocity from the mean are from −7.4 per cent to +7.8 per cent, and for the short run of 50 feet the variations are from −9.5 per cent to +10.7 per cent. For the meter long run the variations are from −7.5 per cent to +12.1 per cent, and for the short run from −6.5 per cent to +6.3 per cent.

Individual measurements of velocity by either of these methods differ much from the mean, but the means by the two methods differ little from each other. The excess of mid-depth velocity by double floats over that by meter may be due to the upper float dragging the lower one.

HENRY'S EXPERIMENTS.

D. F. Henry also gives a comparison of velocity measured with double floats like that shown in fig. 1 and current meter, made on the St. Clair River in 1869.[a] The results of the comparison are given in the following table:

[a] Jour. Franklin Inst., Vol. LXII, p. 322.

Comparison of velocity by double floats and current meter from measurements by D. F. Henry on St. Clair River in 1869.

Number of observations.	Direction and velocity of wind.	Depth of observation below surface.	Velocity of current.		
			Floats.	Meter.	Difference.
	Miles per hour.	*Feet.*	*Ft. per sec.*	*Ft. per sec.*	*Ft. per sec.*
50	3.26 up	1	3.619	3.655	−0.036
62	1.92 up	5	3.759	3.783	−0.024
56	1.27 up	10	3.703	3.674	+0.029
50	0.48 up	15	3.590	3.516	+0.074
54	0.29 down	20	3.598	3.405	+0.193
31	0.53 up	25	3.637	3.441	+0.196
37	0.80 up	30	3.546	3.279	+0.267
29	2.18 down	35	3.556	3.166	+0.390
12	4.85 down	40	3.636	3.142	+0.494
7	0.74 up	45	3.542	2.985	+0.557

It is seen that the float velocity is less than the meter velocity to a depth of about 5 feet. Below that depth the float velocity is greater than the meter velocity, the difference increasing with the depth. The discharge as found with the floats is 10 per cent greater than that found with the meter. While the action of the upper float on the lower float may not account for all the difference between the float and meter velocities, it will account for some of it. The velocity as shown by the vertical velocity curve increases from the surface to a depth of from 5 to 10 feet and then decreases to the bottom. The surface float will therefore move more slowly than the lower float for depths of from 0 to 5 or 10 feet, and hence the lower float will be retarded by the upper float to that depth. For depths greater than 10 feet the upper float will move faster than the lower float and will drag it, and the velocity shown will be too large.

Henry gives also a comparison of velocity as found with double floats and current meter in a small canal at Ogdensburg, N. Y.[a] The floats were run over a distance of 200 feet at 3 feet below the surface, the time being recorded on a chronograph. The current meter was held at the same depth at the middle of the run. The results are as follows:

Comparison of velocity by double floats and current meter from measurements made by D. F. Henry in small canal at Ogdensburg, N. Y., 3 feet below surface.

Number of observations.	Velocity.		
	Floats.	Meter.	Difference.
	Ft. per sec.	*Ft. per sec.*	*Ft. per sec.*
24	1.992	1.980	−0.012
6	1.876	1.916	+0.040
6	1.476	1.434	−0.042

[a] Ibid., p. 259.

These results indicate that although the mean of a few float observations may differ much from the corresponding meter velocity, the means for thirty or forty observations differ little. The meter gives a little smaller velocity than the floats.

Henry also gives a comparison of velocity found with floats and a propeller meter in the St. Clair River. The lower float was 1 foot below the surface, and the meter was held at the same depth. The mean velocity given by fifty floats was 3.619 feet per second; that by meter was 3.655 feet per second, or 0.036 foot per second greater than by floats. There was a light wind blowing upstream, and that may have retarded the floats somewhat.

GORDON'S EXPERIMENTS.

In 1873 Gordon made comparisons of the discharge of the Irawadi River at Saiktha, Burma, as measured with double floats and with current meter. From these he concluded that the double-float discharge was about 10 per cent too large. He therefore reduced all discharges found with double floats by that amount.

FLOAT RODS AND CURRENT METER.

NEW YORK STATE CANAL SURVEY EXPERIMENTS.

During the progress of the New York State canal survey of 1900 comparative discharge measurements were made on four occasions for the purpose of comparing the discharge of the canal as found by one rod-measuring party with that found by another party using similar rods and methods, and of comparing the discharge found with rods with that found simultaneously with a current meter. The results of the comparisons are summarized in the following table:

Comparison of results of experiments of New York State canal survey during the summer of 1900.

Place.	Date.	$V'r$	$V''r$	Vm	$Q'r$	$Q''r$	Qm	$Q'r-Q''r \div Q'r$	$Q'r-Qm \div Q'r$	$Q''r-Qm \div Q''r$
	1900.	*Ft. per sec.*	*Ft. per sec.*	*Ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Per ct.*	*Per ct.*	*Per ct.*
Lockport	Sept. 14	.....	1.440	1.531	.....	805.70	799.85	.....	.....	+0.73
Rochester	Sept. 20	.....	0.704	0.736	.....	235.12	251.57	.....	.....	7.00
Do	Sept. 21	0.893	0.884	.....	297.82	302.04	.....	1.41	.....	.....
Do	....do	.....	0.889	0.929	.....	301.35	310.83	.....	.....	3.14
Do	....do	.....	0.899	0.939	.....	307.08	317.54	.....	.....	3.46
Boonville	Sept. 25	1.073	0.813	.....	227.22	227.51	.....	0.13	.....	.....
Do	....do	.....	0.850	1.079	.....	238.81	228.66	.....	.....	+4.25
Do	....do	.....	0.836	1.111	.....	233.54	234.70	.....	.....	0.49
Glens Falls	Oct. 8	0.821	0.690	.....	164.73	172.77	161.50	−4.88	+1.94	+6.52
Do	....do	0.756	0.640	.....	149.66	158.57	155.23	−5.92	−3.72	+2.11

$V'r$=mean velocity found by party No. 1, with rods.
$V''r$=mean velocity found by party No. 2, with rods.
Vm=mean velocity found with meter, using six-tenths-depth method.
$Q'r$=discharge found by party No. 1, with rods.
$Q''r$=discharge found by party No. 2, with rods.
Qm=discharge found with meter, using six-tenths-depth method.

The Lockport experiments were made on the Erie Canal about 1 mile above the locks at Lockport, in a rock cut with rough, nearly vertical sides. The meter measurements were made 700 feet above the place where the discharge was measured with rods. The observations extended over a period of thirty-four minutes, during which time 60 rods were passed over a run of 21 feet, with an immersion of 80 to 90 per cent of the depth, and 13 meter observations of 50 seconds each were made at six-tenths depth below the surface. There was no measurable fluctuation of surface level during the test.

The Rochester experiments were made on the Rochester Aqueduct, which has smooth and nearly vertical sides. The width was 43 feet and the depth 7.5 feet. The flow was undisturbed for a half mile above the section of measurement, but there was a sharp curve less than 100 feet below the point where the lower rod-measuring party was stationed. In the first comparison of rods with meter, September 20, the period of observation was forty-two minutes; 64 rods were passed over a 20-foot run with 92 per cent depth of immersion; 19 meter observations of fifty seconds each were made by the six-tenths-depth method; the surface level fluctuated 0.05 foot during the observations, and rain interfered somewhat with the work. In the first rod comparison, September 21, the observations extended over a period of sixty-five minutes; 79 rods were passed by party No. 1, with a depth of immersion of from 90 to 97 per cent, and 100 rods by party No. 2, with a depth of immersion of 92 per cent. In the first rod-and-meter comparison of September 21 the period of observation was forty-two minutes; 92 rods were passed by party No. 2, with 90 per cent depth of immersion, and 36 meter observations of fifty seconds each were taken by the six-tenths-depth method. In the second rod-and-meter comparison the period of observation was forty minutes; 80 rods were passed, with 92 per cent depth of immersion, and 36 meter observations of fifty seconds each were made at six-tenths depth.

The Boonville comparisons were made on the Black River Canal at Boonville, where the top width of the canal is 43 feet, with gradual sloping sides, and a maximum depth at center of 7.7 feet. There was an unobstructed flow for at least one-fourth mile above and a half mile below the place selected. The parties were stationed about 200 feet apart. There was practically no water entering or leaving the canal between these points. In the rod comparison, which lasted one hundred and forty-four minutes, with some interruptions, 185 rods were passed over a 20-foot run by party No. 1, and 143 rods by party No. 2. In the first meter comparison, which lasted fifty-eight minutes, 55 rods were passed and 36 meter observations were made at six-tenths depth. In the second meter comparison, which lasted fifty-three minutes, 77 rods were passed and 42 meter observations of fifty seconds each were made by the six-tenths-depth method.

The Glens Falls comparisons were made on the Glens Falls feeder, near Glens Falls. At the place selected for the tests the feeder is 32

feet wide and 6 feet deep, with nearly vertical sides. There is a bend in the feeder about 100 feet above the upper place of measurement, and another about 1,000 feet below the lower place of measurement. The meter measurements were made from a bridge about 100 feet from each of the points where the rod measurements were made. The first comparison lasted seventy-six minutes, during which time party No. 1 passed 56 rods, party No. 2 passed 90 rods, and 28 meter observations of fifty seconds each were made. In the second comparison, which lasted fifty-eight minutes, party No. 1 passed 63 rods, party No. 2 ran 108 rods, and 28 meter observations of fifty seconds each were made.

The method of making these comparisons is the same as that used in the canal discharge measurements, which is described on page 16.

The Rochester and Glens Falls comparisons are not so satisfactory as those at Lockport and Boonville. In the former the measurements were made too near a curve. The large variation in the time of run of the individual rods indicates this fact, and surface-level fluctuations and passing boats interfered somewhat with the work. There is a possibility of leakage from the feeder between the points of measurement at Glens Falls. No leakage was visible on the surface, but there is a large amount of leakage not far distant from the place of measurement. The measurements there indicate a gradual loss from the upper to the lower point of measurement.

The results of the rod comparisons agree more closely than those of meter with rods. It must not be concluded from the Rochester comparisons that because the rod discharges agree closely and the meter discharge differs from the rod discharge 7 per cent that this error is all due to the meter. The two sets of velocity measurements obtained with the meter during this comparison agree closely, whereas the time of run of the individual rods differs considerably. At least half of this difference is due to errors in the rod discharge measurements.

MURPHY'S EXPERIMENTS AT CORNELL UNIVERSITY.

In connection with the writer's experiments at Cornell University to determine the relative accuracy of measurements by the weir and by the current meter, the results of which are discussed on pages 58 to 95, surface velocity experiments were made with float rods and with the current meter, the results of which are given on pages 89 to 92.

FLOAT RODS AND WEIR.

FRANCIS'S EXPERIMENTS.

In 1856 J. B. Francis compared the discharge of a canal at Lowell, Mass., as found with float rods with that shown by a standard weir.[a] This wooden canal or flume was 27.75 feet wide where the first 63 experiments were made and 14 feet wide where the remaining 52

[a] Lowell Hydraulic Experiments, by J. B. Francis, p. 170.

experiments were made. The length of run was 70 feet, with a starting run of 28 feet. The time of run was obtained to a tenth of a second and the depth to 0.0001 foot. Every precaution was taken to obtain accurate results. The floats were tin tubes 2 inches in diameter, loaded at the lower end so as to float upright. They were put in the water at each foot of width of the canal, and the time of run was recorded on a chronograph. The observed velocities were plotted on cross-section paper and a mean curve was drawn among the points showing change in velocity from one side of the canal to the other. The mean velocity in the cross section was found from this curve by dividing the velocity area by the width. The variation of the observed velocities of individual rods from the velocity curve was from 8.57 per cent above to 11.4 per cent below this curve in experiment No. 1. The rods used were not all of the proper depth of immersion, and Francis derived the following formula for computing the correct discharge: $Q'''=Q''[1-0.116(\sqrt{D}-0.1)]$, in which Q'' is the measured discharge and D the depth of water in the flume less the depth of the immersed part of the rod and divided by the depth of water in the flume. After applying this formula he found that the variation of the rod discharge from the weir discharge for the 115 experiments is as follows: For 9 it is less than 0.1 per cent, for 79 it is less than 1 per cent, for 23 it is from 1 per cent to 1.9 per cent, for 2 it is from 2 per cent to 2.9 per cent, and for 1 it is 3.69 per cent. The mean velocity in these experiments varied from 0.5 foot to 5 feet per second.

CORNELL UNIVERSITY EXPERIMENTS.

At the close of the field work of the New York State canal survey of 1900 a series of experiments was made at the hydraulic laboratory of Cornell University for the purpose of comparing discharge as found with rods and current meter on the canals with that shown by the Cornell standard weir. These experiments were planned by the consulting engineer of the New York State canal survey, Mr. E. Kuichling, and were carried out, under the direction of Prof. G. S. Williams, in charge of the hydraulic laboratory, by the writer and by Mr. W. P. Boright, C. E., assisted by members of the class in hydraulics.

The surface level of the sections of the canals fluctuates rapidly on account of lockage of boats and irregular feed of water to lower sections. It was therefore necessary to make discharge measurements rapidly and to make short runs and starting runs. The depth of water in the different sections varied from 5 to 10 feet at the center, so that the immersed portion of the rods used varied from 75 per cent to 95 per cent of the depth of the water. The mean velocity varied from nearly 2 feet per second west of Lockport to 0 on the summit

levels. In the laboratory experiments the conditions were duplicated as closely as possible and the work was performed in the same way as on the canals, so that the results of the comparisons give a fair idea of the accuracy of the discharge measurements of the State canals and feeders.

Pl. II shows the laboratory canal and the observers employed in making the tests. A description of the laboratory and of the method of obtaining standard weir discharge will be found on pages 59 to 64. The gates at the head of the canal were opened until the head on the weir was such as to give the desired discharge; then the slits in the bulkhead and the height of the gates at the lower end of the canal were adjusted so as to give the desired depth of water in the channel. As soon as the flow became steady three parties began measuring the discharge of the canal, one with rods and two with current meters. Two series of rods were used, one of 75 per cent depth of immersion, the other of 90 per cent depth of immersion, the former lettered, the latter numbered, so that they could easily be recognized as they passed under each wire. The lengths of the run and of the starting run were the same as in the canal work, being from 25 to 7 feet for the former and from 10 to 8 feet for the latter, depending on the velocity. The number of rods used in an experiment varied from fifty to one hundred and fifty. Meter party No. 1 measured the discharge by the six-tenths-depth and the integration methods, and then assisted the rod-measuring party, four stop watches being used and the number of rods run in a given time nearly doubled. During each experiment the head on the weir, the depth of water in the canal, and the slope of the surface were read every thirty seconds and were checked occasionally by readings of the hook gage. The time of run of each rod was plotted on squared paper, using distance from side of canal as abscissæ and time of run, in seconds, as ordinates, and a mean time curve was drawn among them. The length of run divided by the mean ordinate of this curve gave the mean velocity, which multiplied by the cross-sectional area gave the discharge. The results of this rod-and-weir discharge comparison are given in the following table:

Comparison of float rod and weir velocity and discharge measurements at Cornell hydraulic laboratory.

Date.	Discharge over standard weir per second.	Rod gagings in laboratory canal.						Error of discharge referred to standard weir.		Mean error of discharge referred to standard weir.	
		Velocity from weir discharge per second.	Depth of water in canal.	Immersion, 75 per cent.		Immersion, 90 per cent.					
				Velocity per second.	Discharge per second.	Velocity per second.	Discharge per second.	75 per cent immersion.	90 per cent immersion.	75 per cent immersion.	90 per cent immersion.
1900.	*Cu. ft.*	*Feet.*	*Feet.*	*Feet.*	*Cu. ft.*	*Feet.*	*Cu. ft.*	*Per. ct.*	*Per. ct.*	*P. ct.*	*P. ct.*
October 24	214.588	1.428	9.356	1.422	213.674	.....	.....	+0.43	.....		
Do	140.514	0.945	9.253	0.962	142.966	0.949	141.034	−1.74	−0.37	1.32	0.75
Do	71.670	0.484	9.222	0.490	72.621	0.476	70.546	−1.33	+1.57		
Do	38.308	0.269	8.789	0.276	38.990	0.272	38.425	−1.78	−0.31		
October 26	178.553	1.473	7.543	1.510	183.185	1.525	184.832	−2.59	−3.52		
Do	125.298	1.033	7.549	1.080	131.000	1.058	128.332	−4.55	−2.42	3.96	2.09
October 27	61.272	0.510	7.471	0.530	63.658	0.520	62.457	−3.89	−1.93		
Do	30.089	0.254	7.376	0.266	31.543	0.255	30.239	−4.83	−0.50		
Do	196.387	1.983	6.163	2.067	204.695	2.044	202.407	−4.23	−3.06		
Do	132.408	1.308	6.299	1.363	137.956	1.341	135.730	−4.19	−2.51	4.22	2.95
Do	91.056	0.910	6.228	0.953	95.372	0.944	94.471	−4.74	−3.64		
Do	50.309	0.535	5.847	0.555	52.176	0.549	51.612	−3.71	−2.59		
October 31	198.258	1.475	8.365	1.537	206.554	1.507	202.523	−4.18	−2.15		
Do	125.299	0.930	8.393	0.958	129.174	.....	.....	−3.09	.....	4.68	2.78
October 29	65.287	0.486	8.355	0.512	68.766	0.501	67.288	−5.33	−3.07		
November 1	31.140	0.235	8.255	0.249	33.043	0.242	32.114	−6.11	−3.13		
										3.54	2.14

It is seen that the discharge obtained with the rods is larger for all depths, velocities, and percentage depths of immersion than the corresponding weir discharge, except in two cases. The greatest variation from the weir discharge is 6.11 per cent for the 75 per cent depth of immersion and 3.64 per cent for the 90 per cent depth of immersion. This variation from the weir discharge, or error, increases as the depth, velocity, and depth of immersion decrease. The mean error for all depths and velocities is 3.54 per cent for the 75 per cent depth of immersion and 2.14 per cent for the 90 per cent depth of immersion. The greatest variations from these means are +1.14 per cent and −2.22 per cent for the 75 per cent depth of immersion and +0.81 per cent and −1.39 per cent for the 90 per cent depth of immersion, a range of 3.4 per cent in the former and 2.2 per cent in the latter. From the last two columns is seen the extent to which the error increases as the depth decreases.

It is to be expected that the rod discharge will be greater than that of the weir, especially for the 75 per cent depth of immersion, for as the rods do not extend to the bottom they are not affected by the bottom layers of slowly moving water, and hence move faster than the mean velocity. By applying Francis's correction formula (p. 54) to these results others will be obtained agreeing more closely with those shown by the weir. It will be shown further on (p. 93) that the weir discharges used in these experiments and computed from Bazin's formula are probably too small by from 0.5 per cent to 2.5 per cent, the former for a head on weir of 1 foot, the latter for a head of 2.5 feet.

When these two sets of corrections are applied it will be found that the rod discharge is correct to within about 2 per cent. This degree of accuracy is only attained, however, by many observations, equivalent to six or twelve gagings, with the rods started 2 feet apart from side to side of canal.

CURRENT METER AND WEIR.

FTELEY AND STEARNS'S EXPERIMENTS.

Fteley and Stearns have made some comparisons of the discharge of the Sudbury conduit as obtained by weir measurement and by current meter.[a] The weir was of the sharp-crested type, 19 feet long, and was located at the head of the conduit. The flow to it was controlled by rectangular gates, which were changed slightly from time to time so as to keep the head on the weir constant. The current-meter measurements were made from a manhole in the conduit 6,000 feet below the weir. The meter used was a Fteley like that shown in fig. 5. Two methods of operating the meter were employed, viz, the point and the integration. When the point method was used the meter was held for thirty seconds at several points in the cross-sectional area, depending on the depth. For the greatest depth of 4.5 feet the number of points of observation was 167. The rate of moving the meter while integrating was from 0.1 foot to 1 foot per second. The results for the 8-vane meter are as follows:

Comparison of discharge measured with 8-vane Fteley meter and over weir.

No. of experiment.	Number of comparisons included in experiment.	Rate of integration.	Depth of center of meter from surface.	Ratio of speed of meter to speed of water.	Mean velocity of water.	Variation of meter discharge from weir discharge.
			Feet.		*Ft. per sec.*	*Per cent.*
1	1	0	1.5	0	1.83	+1.2
2	2	0	2.0	0	2.13	0.0
3	1	0	3.0	0	2.56	+0.1
4	1	0	4.0	0	2.83	+0.1
5	1	0	4.5	0	2.93	−0.4
6	1	0	3.0	0	1.71	0.2
7	3	0.1	1.5	0.055	1.83	+0.8
8	3	0.1	2.0	0.047	2.13	+0.1
9	8	0.1	2.5	0.042	2.37	0.6
10	3	0.1	3.0	0.039	2.56	0.2
11	6	0.1	3.5	0.037	2.71	−0.1
12	4	0.1	4.0	0.035	2.83	−0.5
13	4	0.1	4.5	0.034	2.93	−0.8
14	4	0.1	2.5	0.042	2.37	+0.2
15	16	0.5	2.5	0.211	2.37	3.6
16	15	0.5	3.5	0.185	2.71	−1.8
17	20	1.0	3.5	0.369	2.71	−6.5
18	3	0.1	3.0	0.058	1.71	−1.0
19	4	0.5	3.0	0.292	1.71	−4.5
20	7	1.0	3.0	0.585	1.71	−9.4

The results of experiments Nos. 2 to 6 show a remarkably close agreement between measurements by this meter and those over the

[a] Trans. Am. Soc. Civ. Eng., Vol. XII, p. 301.

weir. The length of an observation, thirty seconds, is too short to give a good average indication of the velocity. The discharge varied somewhat during the experiment. The depth of water in the conduit being small, any error in the depth must have introduced considerable error in the result. We would not expect, therefore, so close an agreement, which appears all the more remarkable when it is seen from the following table that the discharge shown by two weirs may differ by 3 per cent:

Values of m in formula $Q = mlh\sqrt{2gh}$, as found by Bazin and by Fteley and Stearns.[a]

Head on weir (h).	Values of m.		$m_1 - m_2$	$\frac{m_1 - m_2}{m_1}$
	Fteley and Stearns (m_2).	Bazin (m_1).		
Meters.	*Meters.*	*Meters.*	*Meters.*	*Per cent.*
0.1428	0.4149	0.4290	0.0141	3.29
0.1969	0.4166	0.4263	0.0097	2.28
0.2497	0.4191	0.4259	0.0068	1.60
0.3008	0.4218	0.4266	0.0048	1.12
0.3530	0.4247	0.4276	0.0029	0.68
0.3957	0.4272	0.4285	0.0013	0.33
0.4434	0.4296	0.4295	0.0001	0.02
0.4888	0.4323	0.4310	−0.0013	−0.33

It is seen that for heads on the weir of from 0.5 foot to 1 foot the variation in m is from 3 to 1 per cent.

MURPHY'S EXPERIMENTS.

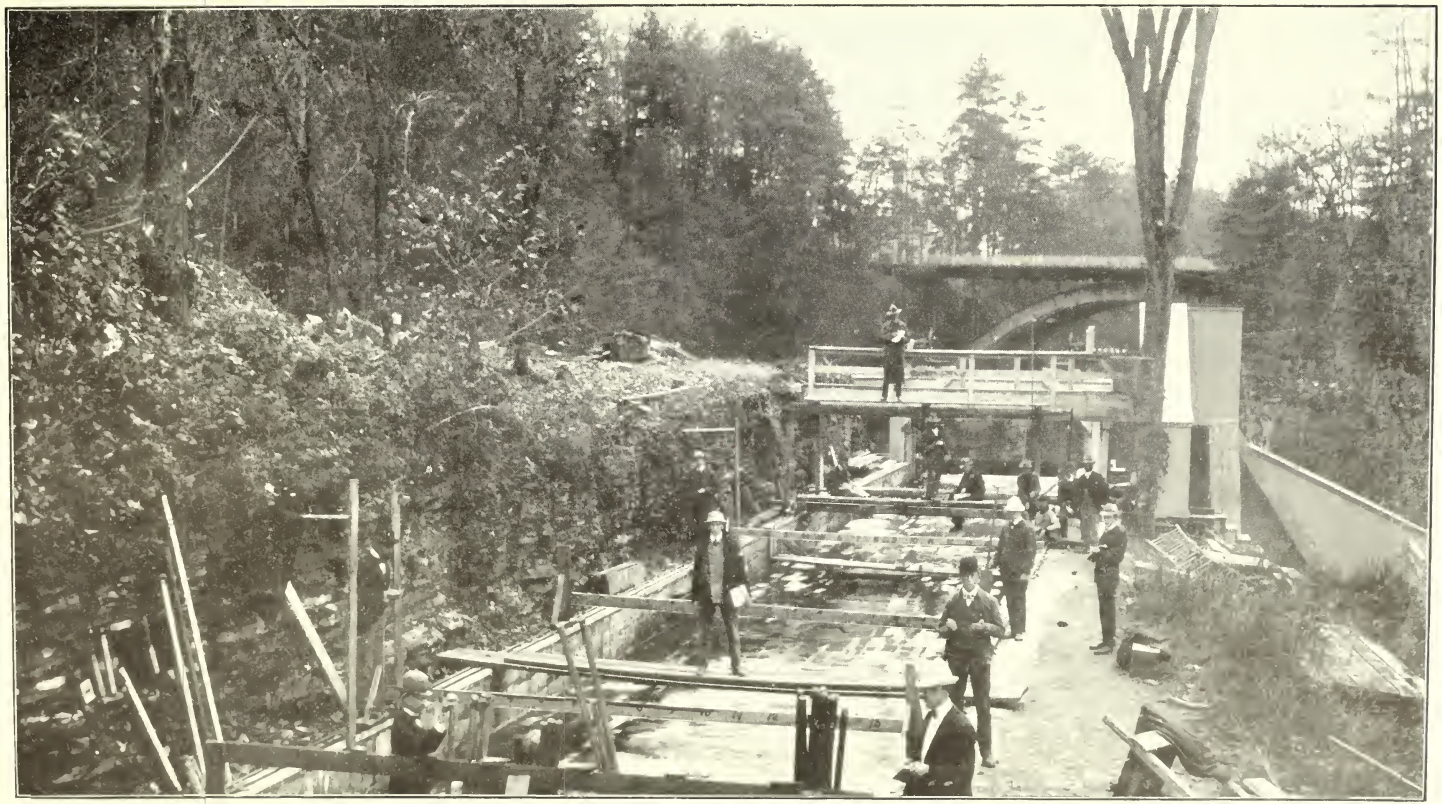
The results of numerous weir, current-meter, and other experiments by the writer at the Cornell hydraulic laboratory are discussed in detail on the following pages; also the application of the results to ordinary river gaging and the general conclusions reached from these recent studies and investigations.

EXPERIMENTS AT CORNELL UNIVERSITY HYDRAULIC LABORATORY.

INTRODUCTORY.

This investigation was begun by the writer in May, 1900, while a fellow in civil engineering at Cornell University. It was interrupted from July 1 to December 4 of that year, on account of the New York State canal survey, in which the writer participated, and again from December 9 to April 1, on account of freezing weather, and was completed in May, 1901. Its object was to compare the discharge of the Cornell University experiment canal as obtained with a sharp-crested weir with that obtained with current meters operated by different

[a] Annales des ponts et chaussées, mémoires et documents, 1888, p. 416.



HYDRAULIC LABORATORY CANAL OF CORNELL UNIVERSITY, SHOWING CORPS ENGAGED IN MAKING DISCHARGE EXPERIMENTS.

methods, and thus determine the accuracy of velocity and discharge obtained by current-meter methods. The scarcity of meters available for the work, the lack of ready facilities for frequent testing and rating of the meters used, and the scarcity of water during the first months of the investigation render the results somewhat less valuable than they otherwise would be.

The writer takes this occasion to acknowledge his indebtedness to Mr. F. H. Newell, chief hydrographer of the United States Geological Survey, for his hearty cooperation; to Prof. E. A. Fuertes, director and dean of the College of Civil Engineering, Cornell University, for the use of the hydraulic laboratory and a chronograph, computing machine, current meter, and electric register, and for kindly interest in the work; to Prof. Gardener S. Williams, in charge of the hydraulic laboratory, for many valuable suggestions and for the use of a chart for converting head on the Cornell University standard weir into cubic meters; also to Mr. C. E. Torrance, scholar in civil engineering, to members of the senior class in civil engineering, and to Mr. C. D. Cass, assistant mechanician of the college, for their cheerful assistance.

DESCRIPTION OF CORNELL HYDRAULIC LABORATORY.

The Cornell hydraulic laboratory consists essentially, as shown in Pls. II, III, and IV and fig. 15, of a canal 16 feet wide, 10 feet deep, and 415 feet long, with concrete bottom and sides and with a bed slope of 1 foot in 500. There are six rectangular gates at the upper end for controlling water entering the canal and four gates near the lower end, two on each side, for controlling the depth of water in the canal. Fifty-nine feet below the entrance gates is a bulkhead about 10.5 feet high built of 12-inch by 12-inch timbers. On the top of this, or 11.1 feet above the bottom of the canal, is fastened a steel angle iron 3.5 inches by 5 inches by 16 feet long, with edges five-sixteenths inch thick, which forms the standard sharp-crested weir. The lower end of the canal is closed with 12-inch by 12-inch timbers, which can be moved up or down if desired and the water be allowed to pass out of the canal at the end instead of under the side gates. In the upper chamber are two sets of baffles for checking the velocity of the water after it passes under the entrance gates. One of these is 7.4 feet from the gates and is made of 4-inch by 12-inch timbers placed horizontally, with the wide face toward the current and spaced from 8 to 12 inches apart. On the upper side of these timbers are 1-inch by 6-inch strips, fastened diagonally and spaced 12 inches from center to center. The second baffle is about 6.5 feet below the first one and is similar in construction, except that the 1-inch by 6-inch strips are placed vertically and are spaced 10 inches from center to center. Twenty-eight feet below the weir is a baffle made of 1-inch by 6-inch strips placed 3 inches from center to center, with the narrow side

toward the current. To still further quiet the waters after passing the weir, when the depth is small and the velocity large, a second baffle was constructed of 1-inch by 6-inch pieces placed vertically, spaced 2 inches from center to center and fastened on the upper side of the baffle just described.

Air is admitted under the falling sheet of water through 12-inch by 10-inch passages in the concrete, one on each side of the weir. The head on the weir and the depth of water in the canal are measured by piezometers and a hook gage. As rough checks on these readings gage boards and a dial gage were occasionally read. The piezometer for giving the head on the standard weir is formed of three 1-inch pipes (P, P, P, fig. 15) perforated for 3 feet of their length with ¼-inch holes 6 inches apart around the pipes. These are placed 27 feet upstream from the weir, with their axes parallel with the axis of the

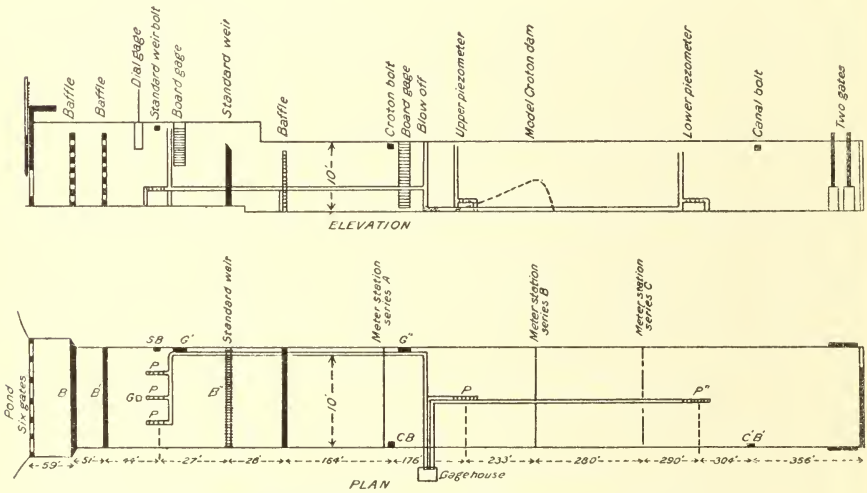


Fig. 15.—Plan and elevation of Cornell University experiment canal.

canal, 4 feet from the bottom, and each connected to a pipe which extends down the south side of the canal to a point opposite the gage house. From this point it is carried across the canal along the bottom and up into the gage house and is connected to a glass tube by a rubber hose. The tube is fastened to a scale marked to 2 mm. spaces. The canal piezometers are similar to those of the weir, but have only one entrance pipe, which is in the center of the canal. The surface elevation of the water was read with the hook gage at the three points in fig. 15 marked "Standard weir bolt," "Croton bolt," and "Canal bolt," the elevation of each of which is known. The dial gage and the board gage G' show approximately the head on the standard weir in feet and hundredths and enable the man operating the gates to keep a nearly constant head. A board gage (G'') opposite the "Croton bolt" (CB) shows approximately the depth of water in the canal.

FLUME, PENSTOCK, AND WHEEL HOUSE OF CORNELL HYDRAULIC LABORATORY CANAL.

SCOPE OF EXPERIMENTS.

The experiments naturally divide themselves into five groups, which we have called series A, B, C, D, and E. The experiments of series A were made at a section 158 feet below the standard weir and 75 feet upstream from a model of the Croton dam the height of which was 6 feet and the upstream face of which had a gradual slope and extended to within 29 feet of the meter station. This model dam formed a pool above it at the meter station and gave a zero velocity for 6 feet depth of water. The range of depths and velocities was therefore small. The water surface during the experiments was smooth, without boiling or swirls, with most of the foam made by the water falling over the weir moving down in two parallel lines 3 or 4 feet from each side. Three current meters were used in this series of experiments, viz, large Price meter No. 88, small Price meter No. 351, and the Cornell University Fteley meter. The latter was always held with a rod, the small Price meter was held with a cable, and the large Price meter with a cable in some of the experiments and with a rod in other experiments. About 3¼ inches of mud had accumulated on the bottom of the canal above the model dam. After the first two experiments the mud was removed for a space of 4 or 5 feet above and below the meter station. For all other experiments the bottom was clean and smooth.

The experiments of series B were made 234 feet below the standard weir and after the model dam had been removed. They are with high velocities and shallow depths, the scarcity of water at the time restricting the depth somewhat. In all these experiments except Nos. 6 and 8 the tail gates were open, so that there was no backwater. The surface of the water was quite rough, being a succession of waves, without swirls or boiling. (See Pl. IV.) The same three meters were used as in series A. The Fteley and the large Price were held with rods, the small Price was held with a rod in some of the experiments and with a cable in other experiments.

The experiments of series C were made 280 feet below the standard weir, as part of the tests of accuracy of the discharge measurements of the New York State canals and feeders made during the summer of 1900. They cover a range of depths from 6 to 9.5 feet and velocities from 0.23 foot to 2 feet per second. In most of the experiments of this series nearly all of the water was passed out of the canal through horizontal slits in the bulkhead. The water surface was comparatively smooth, being a succession of long waves, without boiling or swirls. Two meters were used—small Price No. 363, operated by the six-tenths-depth and integration methods, and small Price No. 351, operated by the ordinary method. The former was held with a cable, the latter with a rod.

The experiments of series D were made 220 feet below the standard weir, with Haskell meter No. 3 and small Price meter No. 363, each

held with a cable. The range of depth was from 5 to 9.5 feet, and the velocities from 0.25 foot to 2 feet. The water surface was like that in series C—long waves, without boiling or swirls. Three methods of obtaining velocity were used—the ordinary, the six-tenths, and the integration. This series is not complete, the work being stopped by the freezing of the canal. The piezometers could not be used on account of the freezing of the pipes. The hook gage only was used to measure the head on the weir and the depth of water in the canal.

The experiments of series E were made with two small Price meters and a Haskell meter, held with cables at station 220 feet below the standard weir. The depth in this series varied from 4.6 feet to 9.3 feet, and the mean velocity from 1.5 feet to 3 feet per second. It was designed to extend the results of the previous year to the higher velocities. The discharge measurements were made in pairs, as in series D, so as to compare the results of two meters with each other as well as the results of each meter with the corresponding weir discharge. The head on the weir and the elevation of water surface were obtained from readings of the portable hook gage. The water surface was quite rough for these higher velocities, being a succession of waves, without swirls. To quiet it and enable the surface elevation to be more accurately measured, in experiments 9 to 22 two planks, 2 inches by 12 inches by 15 feet long, were placed across the canal about 3 feet apart and 154 feet from the weir, fastened at the ends so as to float on the surface and break the force of the waves. In experiments 23 to 50 three of these planks were used. The planks served their purpose very well, but distorted somewhat the vertical velocity curves.

METHOD OF EXPERIMENTATION.

The first operation in each experiment was to adjust the entrance gates to admit such a quantity of water that with the desired depth of water at the meter station the velocity would be about the desired rate. The tail gates were then opened or closed somewhat, as the case required, until the water reached the desired depth and remained steady. The standard weir gage was then read every thirty seconds and the canal gages (one or both) were read every five minutes during the time the meter observations were being taken. When the hook gage was used it was read six times in succession, as quickly as possible, at each of the three points in fig. 15 marked "Standard bolt," "Croton bolt," and "Canal bolt," already described. When the ordinary method of operating the meter was used the meter was held at from two to six points, depending on the depth, in each of from five to eight verticals, and the number of the revolutions of the meter wheel in from one to two periods of from thirty to sixty seconds each was obtained. Usually it was two periods of fifty seconds each. In series C, ordinary method, one period of sixty seconds was used and the revolutions were read on a recorder. In all the other experiments except those

CORNELL HYDRAULIC LABORATORY CANAL, SHOWING DISTURBED WATER SURFACE DURING EXPERIMENTS IN SERIES B.

with the Fteley meter the revolutions were obtained from indications of an electric buzzer. When the meter was operated by the six-tenths-depth method it was held at about six-tenths depth below the surface in eight verticals, viz, 1, 3, 5, 7, 9, 11, 13, and 15 feet from the south side of the canal, and the revolutions were obtained for two periods of fifty seconds each. The meter was then held at the same depth in the same verticals in the inverse order, i. e., 15, 13, etc., 1 foot from the south side of the canal, and the revolutions were again counted for two periods of fifty seconds each. When the integration method was used in series C the meter was moved in the following way: It was started at 1 foot from the bottom (center of meter 0.5 foot above bottom) and 1 foot from the side of the canal, and was passed slowly to the surface at 4.5 feet from the side, then to the bottom at 8 feet from the side, then to the surface at 11.5 feet from the side, and then to the bottom at 15 feet from the side. The time at the beginning and end was noted and the total number of revolutions were counted. The meter was then carried back over the same path at about the same speed, and the time of passage and the number of revolutions were obtained as before. The mean time and the mean number of revolutions of these two passages across the canal are used as a single experiment. When this method was used in series A the meter was carried only once across the canal, and it was started and stopped at the bottom (center of meter 0.5 foot above bottom) and close to each side, and reached the surface 4 feet and 12 feet from the south side of the canal. When this method was used in series E the meter was moved slowly from the surface to the bottom (center of meter from 2.5 inches below surface to 5.5 inches above bottom) and back to the surface in each of the eight verticals in which the meter was held when the ordinary point method was used. The time of passage of the meter down and back again in each vertical was noted and the revolutions of the meter wheel were counted.

REDUCTION OF EXPERIMENTS.

The standard weir gage readings were averaged for the time of each discharge measurement, and the reading for zero head subtracted, giving the head on the weir in double centimeters. By means of a chart for converting head on weir into cubic meters per second and a computing machine the discharge in cubic feet per second was easily obtained. The depth of water in the canal was found by adding to the mean canal gage reading in feet the difference in elevation of the canal bottom and the zero of the scale. The discharge when the ordinary method was used was computed from the vertical velocity curve for that experiment (see figs. 23 to 28). The observations were usually taken in the eight verticals at 1, 3, 5, 7, 9, 11, 13, and 15 feet from the south side of the canal, and at the same distance above the bottom. When observations in any vertical were missing, as in ver-

ticals 7 and 11 in series C, they were supplied by interpolation. The mean number of revolutions at the depth of each observation for these eight verticals was then found, converted into velocity by the rating table, plotted (as in figs. 23 to 28), and a mean curve drawn. The mean abscissa of this curve is the mean velocity in the cross section; the discharge is the product of this velocity and the cross-sectional area.

When the six-tenths-depth method was used a horizontal curve of velocity was drawn in a similar manner and the mean velocity was found from it. The mean velocity by the integration method was obtained by dividing the revolutions by the corresponding time and converting the quotient into velocity.

DISCUSSION OF RESULTS.

COMPARISONS OF DISCHARGE MEASUREMENTS.

The following tables give the results of the discharge comparisons of series A to D. The standard weir discharge (third column) is the mean for the time over which the meter observations (ordinary method) extended. It is assumed to be the same for the shorter period of measuring the discharge by the six-tenths-depth and the integration methods. This is not strictly true for the larger discharges, but it is near enough for practical purposes. The true velocity is obtained by dividing the weir discharge by the cross-sectional area at the meter station. The other columns are self-explanatory.

Comparisons of discharge over Cornell University standard weir with measurements by current meters.

SERIES A.

Date.	No. of experiment.	Standard weir discharge (Q).	Meter observations.								Variation.	
			Depth of water in canal at meter section.	True velocity (V) at meter section.	Kind of meter.	Number of observations.	Ordinary method.		Integration method.			
							V_0	Q_1	V_1	Q_1	$\frac{Q-Q_0}{Q}$	$\frac{Q-Q_1}{Q}$
1900.		*Cu. ft. per sec.*	*Feet.*	*Feet p. sec.*	(a)		*Feet p. sec.*	*Cu. ft. per sec.*	*Feet p. sec.*	*Cu. ft. per sec.*	*Per ct.*	*Per ct.*
May 5	1	147.991	7.996	1.166	L. P. 88	76	1.097	138.478	.....	.....	+ 6.43	.....
Do	2	65.024	7.167	0.573	do	29	0.447	50.714	.....	.....	+22.01	.....
May 7	3	78.481	7.258	0.683	Fteley	31	0.677	77.780	.....	.....	+ 0.90	.....
May 8	4	162.684	8.104	1.268	S. P. 351	38	1.267	162.464	1.252	160.62	+ 0.14	+1.26
Do	5	100.379	7.542	0.841	do	20	0.790	94.318	.....	.....	+ 6.03	.....
May 9	6	193.624	8.369	1.462	do	35	1.435	190.109	.....	.....	+ 1.81	.....
Do	7	131.178	7.845	1.056	do	18	1.036	128.657	1.031	128.04	+ 1.92	+2.32
Do	8	131.037	7.848	1.056	L. P. 88	18	0.982	122.000	1.006	124.98	+ 6.90	+4.63
Do	9	131.072	7.845	1.055	Fteley	18	1.148	142.570	.....	.....	− 8.77	.....
May 15	10	148.556	7.984	1.175	do	40	1.286	162.540	.....	.....	− 9.43	.....
Do	11	119.947	7.729	0.980	S. P. 351	32	0.939	114.887	0.978	119.66	+ 4.22	+0.26
May 16	12	74.137	7.281	0.643	L. P. 88	36	0.533	61.432	.....	.....	+17.14	.....
Do	13	93.457	7.484	0.788	do	32	0.744	88.110	.....	.....	+ 5.72	.....
Do	14	74.137	7.280	0.643	Fteley	29	0.642	73.985	.....	.....	+ 0.20	.....
Do	15	93.386	7.484	0.788	do	32	0.834	98.804	.....	.....	− 5.80	.....

[a] L. P. = large Price; S. P. = small Price. The figures given are the meter numbers.

Comparisons of discharge over Cornell University standard weir with measurements by current meters—Continued.

SERIES B.

Date.	No. of experiment.	Standard weir discharge (Q).	Meter observations.						Variation. $\frac{Q-Q_0}{Q}$
			Depth of water in canal at meter section.	True velocity (V) at meter section.	Kind of meter.	Number of observations.	Ordinary method. V_0	Ordinary method. Q_0	
		Cu. ft. per sec.	*Feet per sec.*	*Feet per sec.*	(a)		*Feet per sec.*	*Cu. ft. per sec.*	*Per ct*
1900.									
May 19	1	50.366	1.115	2.823	S. P. 351	16	2.790	49.774	+ 1.11
Do	2	50.260	1.115	2.823	Fteley	16	3.599	64.206	−27.75
Do	3	50.154	1.110	2.824	L. P. 88	16	3.103	53.790	− 7.26
May 21	4	65.625	1.299	3.157	Fteley	24	3.344	69.502	− 5.91
Do	5	65.625	1.299	3.157	L. P. 88	24	3.085	64.118	+ 2.36
Do	6	66.896	2.000	2.091	Fteley	24	2.500	80.000	−18.09
Do	7	21.616	0.786	1.719	L. P. 88	16	1.538	19.341	+ 10.54
Do	8	66.731	2.029	2.056	....do	24	1.900	61.682	+ 9.07
Do	9	33.060	0.744	2.766	Fteley	16	3.273	32.295	+ 2.30
May 22	10	21.369	0.550	2.428	....do	16	2.945	25.916	−21.28
Do	11	94.410	1.885	3.130	....do	24	3.789	114.250	−21.01
Do	12	94.410	1.885	3.130	L. P. 88	24	3.102	93.556	+ 0.90
Do	13	57.854	1.198	3.018	Fteley	24	3.720	71.305	−23.27
Do	14	57.854	1.198	3.018	L. P. 88	24	2.947	56.589	+ 2.18
Do	15	43.761	0.953	2.870	S. P. 351	16	2.698	43.055	+ 1.62
Do	16	43.761	0.953	2.870	Fteley	16	3.474	52.944	−20.98
Do	17	29.598	0.693	2.671	S. P. 351	16	2.425	26.876	+ 9.19
Do	18	29.598	0.693	2.671	Fteley	16	3.137	34.768	−17.47
Do	19	18.932	0.464	2.553	S. P. 351	8	2.290	16.983	−10.30
Do	20	18.932	0.464	2.553	Fteley	8	2.932	21.744	−14.84

a L. P. = large Price; S. P. = small Price. The figures given are the meter numbers.

Comparison of discharge over Cornell University standard weir with measurements by current meters.

SERIES C

Date.	Number of experiment.	Standard weir discharge (Q).	Meter observations.							Variation.		
			Depth of water in canal at meter section.	True velocity (V) at meter section.	Small Price No. 351, ordinary method.		Small Price No. 363.			Small Price No. 351, $\left(\frac{Q-Q_0}{Q}\right)$.	Small Price No. 363.	
							Ordinary method.		Integration method, (Q_1).		$\frac{Q-Q_6}{Q}$	$\frac{Q-Q_1}{Q}$
					V_0	Q_0	V_6	Q_6				
1900.		*Cu. ft. per sec.*	*Feet.*	*Ft. per. sec.*	*Ft. per sec.*	*Cu. ft. per sec.*	*Ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Per cent.*	*Per cent.*	*Per cent.*
October 24	1	216.131	9.460	1.409	1.446	219.836	1.465	222.980	220.393	− 1.77	−4.11	− 0.63
Do	2	140.515	9.374	0.932	0.969	146.060	0.985	148.528	143.099	− 4.13	−6.13	− 5.37
Do	3	71.681	9.338	0.477	0.493	73.050	0.487	73.167	71.514	− 2.38	−2.08	− 1.59
Do	4	38.254	8.910	0.265	0.259	37.420	0.278	40.113	33.330	+ 2.03	−6.00	−16.16
October 26	5	178.553	7.673	1.444	1.449	179.130	1.489	184.075	174.679	− 0.53	−3.09	− 5.17
Do	6	125.298	7.640	1.018	0.999	122.974	1.047	128.880	120.789	+ 1.85	−2.78	− 5.12
October 27	7	61.272	7.582	0.502	----------	----------	0.522	63.771	61.327	----------	−4.88	− 4.08
Do	8	31.176	7.557	0.255	0.215	26.180	0.258	31.488	28.070	+16.01	−1.04	−22.10
Do	9	50.310	6.005	0.515	0.494	48.208	0.540	52.696	46.451	+ 4.17	−5.92	− 7.65
Do	10	196.387	6.278	1.940	1.890	192.799	1.989	201.367	188.232	+ 1.83	−1.46	− 4.86
Do	11	132.414	6.399	1.283	1.251	129.078	1.318	135.991	123.816	+ 2.52	−3.18	− 4.27
Do	12	91.056	6.319	0.893	0.847	86.318	0.920	93.758	83.872	+ 5.20	−5.08	− 2.96
October 29	13	65.319	8.476	0.478	0.464	63.325	0.492	67.146	60.459	+ 3.07	−2.35	− 2.80
October 31	14	198.258	8.470	1.454	1.460	199.115	1.514	206.480	187.795	− 0.44	−3.71	− 6.76
Do	15	125.301	8.508	0.915	0.890	121.921	0.949	130.601	114.522	+ 2.69	−3.75	− 9.54
November 1	16	31.223	8.455	0.229	0.201	27.364	0.240	32.674	25.186	+12.37	−2.47	−39.30

Comparison of discharge over Cornell University standard weir with measurements by current meters—Continued.

SERIES D.

Date.	Number of experiment.	Standard weir discharge (Q).	Meter observations.							Variation.		
			Depth of water in canal at meter section.	True velocity (V) at meter section.	Kind of meter.[a]	Ordinary method.		Six-tenths-depth method (Q_6).	Integration method (Q_1).	$\frac{Q-Q_0}{Q}$	$\frac{Q-Q_6}{Q}$	$\frac{Q-Q_1}{Q}$
						V_0	Q_0					
1900.		*Cu. ft. per sec.*	*Feet.*	*Ft. per sec.*		*Ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Per cent.*	*Per cent.*	*Per cent.*
December 6	1	233.262	9.505	1.528	S. P. 363	1.519	231.976		235.082	+0.55		−0.77
Do	2	233.262	9.505	1.528	Hask. 3	1.484	226.380		239.968	+2.95		−2.88
December 7	3	229.731	9.317	1.535	do			239.120	235.828		− 4.09	−2.66
Do	4	117.673	[b] 9.536	0.768	do	0.832	[b] 127.421	[b] 126.498		−8.28	− 7.50	
Do	5	117.673	[b] 9.536	0.768	S. P. 363	0.794	[b] 121.602	[b] 119.301		−3.34	− 1.40	
Do	6	95.176	[b] 9.524	0.622	Hask. 3	0.676	[b] 103.401	[b] 105.846		−8.63	−11.21	
Do	7	95.176	[b] 9.524		S. P. 363	0.563	[b] 99.883	[b] 97.892		−4.93	− 2.84	
December 8	8	221.749	7.245	1.905	Hask. 3	1.864	216.932	218.680	228.340	+2.13	+ 1.38	−3.08
Do	9	221.749	7.245	1.905	S. P. 363	1.867	217.281	222.521		+2.01	− 0.35	
Do	10	191.165	7.217	1.649	Hask. 3	1.675	194.183	200.209	202.647	−1.58	− 4.73	−6.00
Do	11	191.165	7.217	1.649	S. P. 363	1.651	191.400	192.793		+0.20	− 0.84	
Do	12	110.186	7.183	0.955	Hask. 3	1.022	117.919	118.802	119.609	−7.01	− 7.84	−8.55
Do	13	110.186		0.955	S. P. 363	0.955	110.188	110.858		0.00	− 0.68	
Do	14	55.717	7.113	0.496	Hask. 3			53.244			− 6.14	
					S. P. 363			58.270			− 2.73	
Do	15	57.071	5.154	0.689	Hask. 3	0.730	60.455	62.277	62.277	−5.94	9.10	−9.10
Do	16	57.071	5.154	0.689	S. P. 363	0.672	55.651	57.308		+2.49	0.42	

[a] S. P. = small Price; Hask. = Haskell. The figures given are the meter numbers.

[b] Hook gage broken; depth not accurately measured.

It is seen from the foregoing tables that the meter discharge differs from the weir discharge all the way from 0 to 40 per cent. One might say, without careful examination, that the current meter must be a very unreliable velocity-measuring instrument; but when we examine these results carefully and plot them according to velocity we find the case very different. Take first the results by the ordinary method.

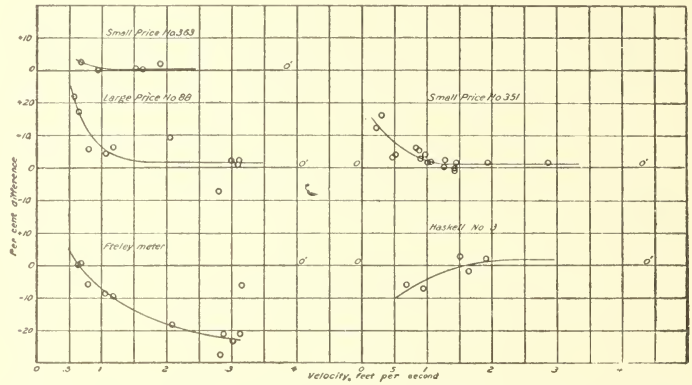


FIG. 16.—Diagram showing difference between meter discharge by ordinary method and weir discharge, from measurements in Cornell University experiment canal. Line 0-0′ represents weir discharge.

These are plotted for each meter in fig. 16, using mean velocity as abscissæ and percentage difference as ordinates. It is seen that nearly all of these points fall on well-defined lines. The few exceptions are those in which the depth is small and the errors of depth and position of meter have a large effect on the measured discharge. The discharge obtained with the Fteley meter differs more from the corre-

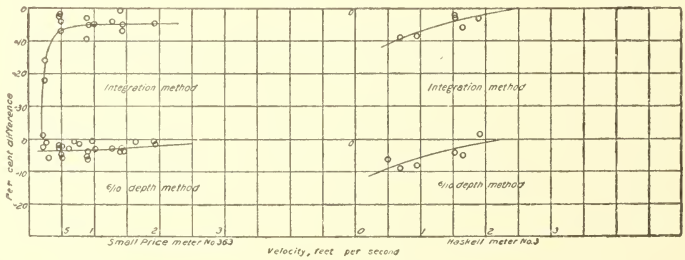


FIG. 17.—Diagram showing difference between meter discharge by six-tenths-depth and integration methods and weir discharge, from measurements in Cornell University experiment canal. Line 0-0′ represents weir discharge.

sponding weir discharge than that obtained with the other meters. This is because it had never been rated. The constant we have used in reducing the observations with this meter—viz, 1 revolution per second at 1 foot velocity = 1.072—was obtained from observations by students. It is not, however, much in error for this velocity, but is largely in error for other velocities. The rating obtained from these weir experiments is given in the table on page 81. For the other

three meters the percentage error is small for velocities above 1 foot per second. For the Price meters the error is positive and increases rapidly as the velocity decreases. For the Haskell meter the error is negative and increases, negatively, rapidly as the velocity decreases. The error in rating, if we may call it such, is not so large as it appears from these diagrams, for a 10-per cent error in a small quantity is only a 1-per cent error in a quantity ten times as large. The rating tables as derived from these curves and as found by moving the meter through still water are given in the table on page 81. Experiments with depths of 0.75 foot or less (Nos. 9 and 17 to 20 of series B) are not plotted in the diagram (fig. 16), as the probable error is large; nor are experiments 1 to 4 of series C, because the upper and lower parts of the vertical curves are not well defined; nor experiments 4 to 7 of series D, because there appears to be an error in the hook-gage work of those experiments.

In fig. 17 are plotted the percentage differences between weir discharge and discharge obtained by the six-tenths-depth and the integration methods. It is seen that the meter discharge by these methods is greater than the weir discharge, being 4 or 5 per cent greater for velocities above 1 foot per second. In the integration method, for small velocities the difference increases very rapidly as the velocity decreases. It is seen from figs. 16 and 17 that while the ordinary method gives discharge 1 or 2 per cent less than the weir for velocities above 1 foot per second, the six-tenths-depth and the integration methods give discharge 4 or 5 per cent greater than the weir.

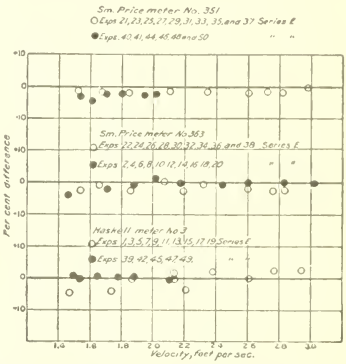


FIG. 18. Diagram showing difference between meter discharge with different meters and weir discharge in experiments of series E in Cornell University experiment canal. Zero line indicates weir discharge.

The results of the discharge measurements of series E are given in the following table and are plotted in fig. 18, which shows three sets of double comparisons. Experiments 1 to 20 give a comparison of simultaneous measurements with small Price meter No. 363 and Haskell meter No. 3, and also with the discharge obtained at the same time with the weir. Experiments 21 to 38 give similar comparisons for the two small Price meters and the weir, and experiments 39 to 50 give similar comparisons for Haskell and Price meters and the weir.

Comparison of discharge over Cornell University standard weir with measurements by current meters.

SERIES E.

No. of experiment.	Date.	Depth of water in canal at meter section.	True velocity at meter section.	Standard weir discharge (Q).	Meter discharge (Q_w).	Variation $\left(\frac{Q-Q_w}{Q_w}\right)$.	Kind of meter.[a]	Difference in meter discharges.
	1901.	*Feet.*	*Ft. per sec.*	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Per cent.*		*Per cent.*
1	April 1	9.075	1.472	204.41	214.08	−4.73	Hask. 3	0.86
2	do	9.075	1.456	204.41	212.33	−3.87	S. P. 363	
3	April 2	6.079	2.208	208.88	216.28	−3.54	Hask. 3	0.99
4	do	6.079	2.187	208.88	214.22	−2.55	S. P. 363	
5	do	7.453	1.744	200.81	208.85	−4.00	Hask. 3	2.03
6	do	7.453	1.710	200.81	204.77	−1.97	S. P. 363	
7	do	5.742	2.137	197.64	197.02	0.31	Hask. 3	1.58
8	do	5.742	2.171	197.64	200.15	+1.27	S. P. 363	
9	April 5	7.409	1.869	222.67	222.68	0.00	Hask. 3	0.75
10	do	7.409	1.883	222.67	224.35	−0.75	S. P. 363	
11	do	6.295	2.137	220.33	216.00	+1.96	Hask. 3	1.82
12	do	6.295	2.177	220.33	220.03	+0.14	S. P. 363	
13	do	5.628	2.377	219.38	214.82	+2.08	Hask. 3	2.51
14	do	5.628	2.438	219.38	220.33	−0.43	S. P. 363	
15	do	5.294	2.611	221.96	222.02	−0.03	Hask. 3	0.34
16	do	5.294	2.602	221.96	221.27	+0.31	S. P. 363	
17	do	4.892	2.764	222.81	217.32	+2.46	Hask. 3	2.22
18	do	4.892	2.827	222.81	222.27	+0.24	S. P. 363	
19	do	4.617	2.936	224.75	218.32	+2.86	Hask. 3	2.85
20	do	4.617	3.019	224.75	224.50	+0.01	S. P. 363	
								1.60
21	April 6	4.808	2.985	230.36	230.66	−0.13	S. P. 351	0.71
22	do	4.808	3.006	230.36	232.30	−0.84	S. P. 363	
23	April 10	8.744	1.670	230.75	234.68	−1.70	S. P. 351	0.71
24	do	8.744	1.657	230.75	232.85	−0.99	S. P. 363	
25	do	7.874	1.846	229.28	233.61	−1.89	S. P. 351	0.88
26	do	7.874	1.862	229.28	235.64	−2.77	S. P. 363	
27	do	6.889	2.108	229.91	233.25	−1.45	S. P. 351	1.68
28	do	6.889	2.073	229.91	229.38	+0.23	S. P. 363	
29	April 11	6.129	2.340	227.16	230.25	−1.36	S. P. 351	0.86
30	do	6.129	2.320	227.16	228.28	−0.50	S. P. 363	
31	do	5.483	2.596	225.01	228.59	−1.60	S. P. 351	0.31
32	do	5.483	2.604	225.01	229.30	−1.91	S. P. 363	
33	do	5.185	2.725	224.06	226.98	−1.30	S. P. 351	1.23
34	do	5.185	2.758	224.06	229.73	−2.53	S. P. 363	
35	do	5.003	2.816	222.60	226.37	−1.69	S. P. 351	0.65
36	do	5.003	2.834	222.60	227.82	−2.34	S. P. 363	
37	do	9.256	1.522	223.40	226.38	−1.33	S. P. 351	1.05
38	do	9.256	1.538	223.40	228.71	−2.38	S. P. 363	
								0.90
39	April 12	9.344	1.486	224.63	223.11	+0.68	Hask. 3	3.68
40	do	9.344	1.541	224.63	231.37	−3.00	S. P. 351	
41	do	8.934	1.613	221.39	231.58	−4.60	S. P. 351	4.67
42	do	8.934	1.543	221.39	221.53	+0.07	Hask. 3	
43	do	8.297	1.646	221.39	219.50	+0.81	do	3.21
44	do	8.297	1.700	221.39	226.70	−2.40	S. P. 351	
45	do	7.806	1.775	221.49	222.69	+0.54	Hask. 3	2.61
46	do	7.806	1.803	221.49	226.19	−2.07	S. P. 351	
47	do	7.266	1.879	221.21	219.34	+0.85	Hask. 3	3.38
48	do	7.266	1.943	221.21	226.81	−2.53	S. P. 351	
49	do	6.439	2.132	221.03	220.43	+0.27	Hask. 3	1.80
50	do	6.439	2.182	221.03	225.61	−2.07	S. P. 351	
								3.22

[a] S. P. = small Price; Hask. = Haskell. The figures given are the meter numbers.

The principal results of the foregoing comparisons have been condensed in the following table:

Table showing percentage variation between weir discharge and meter discharge, and between meter discharge by different instruments of experiments in series E.

Experiments.	Kind of meter.	Difference between standard weir discharge and meter discharge.				Difference in discharge of simultaneous meter measurements.			
		Max.	Min.	Mean.[a]	Range.	Max.	Min.	Mean.	Range.
		Per ct.	*Per ct.*	*Per ct.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1 to 20	Haskell No. 3	−4.73	0.00	−0.33	−4.73 to +2.86	.....	.....	.....	.....
Do	S. Price No. 363	−3.87	+0.01	−0.76	−3.87 to +1.27	2.85	0.34	[a] 0.29 [b] 1.60	2.51
21 to 38	S. Price No. 351	−1.89	−0.13	−1.38	−1.89 to 0.13	.....	.....	.....	.....
Do	S. Price No. 363	−2.77	+0.23	−1.56	−2.77 to +0.23	1.68	0.31	[a] 0.18 [b] 0.90	1.37
39 to 50	S. Price No. 351	−4.60	−2.07	−2.78	−4.60 to −2.07	.....	.....	.....	.....
Do	Haskell No. 3	+0.85	−0.27	+0.40	+0.85 to −0.27	4.67	1.80	[a] 3.22 [b] 3.22	2.87

[a] Regarding signs. [b] Disregarding signs.

It is seen from this that in none of these fifty experiments does a meter discharge differ from a corresponding weir discharge 5 per cent, and in no case do two simultaneous meter discharges differ from each other 5 per cent. In experiments 1 to 20 the mean variation from the weir discharge is −0.33 per cent for the Haskell meter and −0.76 per cent for the Price meter, while the mean difference between corresponding meter discharges is 0.29 per cent. In experiments 21 to 38 the mean variation from the weir discharge is 1.38 per cent for Price meter No. 351 and −1.56 per cent for Price meter No. 363, while the mean difference between corresponding meter discharges is 0.18 per cent. In experiments 39 to 50 the mean variation from the weir discharge is 2.78 per cent for the Price meter and 0.40 per cent for the Haskell meter, while the mean difference between corresponding meter discharges is 3.22 per cent.

The range of variation of meter discharge from weir discharge is greater than that of corresponding meter discharges. This is to be expected, however, since there are a number of possible errors in the former which are not in the latter. Errors in measuring head, depth, calibration of weir, velocity, and rating of meter affect the former, while only the two latter errors affect corresponding meter discharges.

It is also seen that the mean of the difference between simultaneous discharge measurements Nos. 21 to 38 is only 0.18 per cent, and the extreme range in these eighteen consecutive measurements is only 1.37 per cent. How much of this error is due to errors in the rating table and how much to errors in observing velocity we were unable to determine, as good facilities for rating were not at hand. We are, however, justified by these experiments in the statement that the discharge of this canal can, with a small Price meter, be measured to within less than 1 per cent when the mean velocity in the canal is from 1.5 feet to 3 feet per second.

VELOCITY CURVES.

Curves of equal velocity in the cross-sectional area of observation are shown in figs. 19, 20, 21, and 22. Four experiments are selected (one from each series) from the sixty-five experiments of series A to D by the ordinary method, to show the variation of velocity in the sections. They are self-explanatory. Fig. 20 illustrates a case of small depth, high velocity, and no back-water effect. The maximum velocity is at the surface, nearly midway between the banks. In figs. 19, 21, and 22 the maximum velocity is below the surface and not midway between the banks. It is less at the center than 3 or 4 feet from either side. This is true of all the experiments of series A. We tried admitting the water to the upper chamber of the canal in various ways, by opening some of the gates and closing or partly closing others, but the distribution of velocity appeared to be nearly independent of the openings through which the water was admitted to the canal.

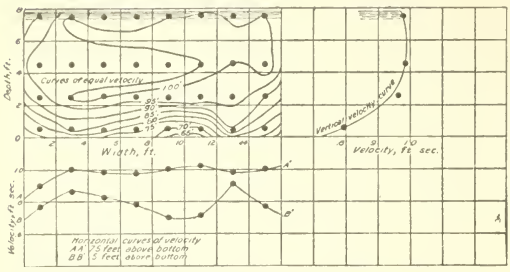


FIG. 19.—Curves of equal velocity in experiment No. 11, series A.

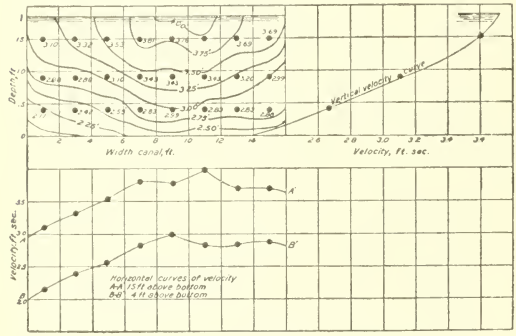


FIG. 20.—Curves of equal velocity in experiment No. 12, series B, with large Price meter No. 88.

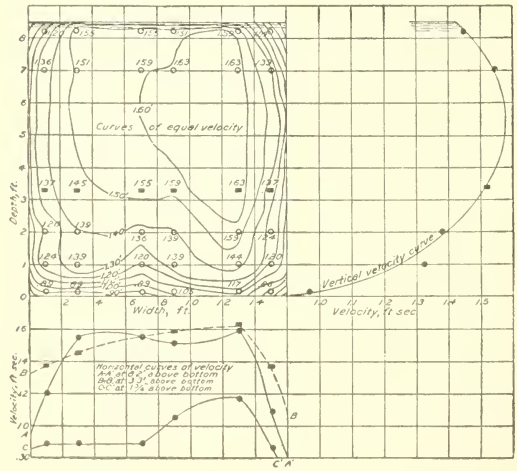


FIG. 21.—Curves of equal velocity in experiment No. 14, series C. The dots are for small Price meter No. 351; heavy black squares for small Price meter No. 363.

Horizontal velocity curves are shown in these same figures (19 to 22), the velocity curve at six-tenths depth below the surface being shown, and also the curves for surface and bottom. In these figures the velocity

near the north side of the canal is somewhat less than that near the south side. This is true of all the experiments of series C and D. It is due to the north side of the canal being much rougher than the south side, the concrete of the north side having been cut away preparatory to its repair just previous to making the experiments of series C.

Vertical velocity curves for these four series of experiments (A to D) are shown in figs. 23 to 28. Each of these curves is the mean of observations in the eight verticals 1, 3, 5, 7, 9, 11, 13, and 15 feet from the south side of the canal. For series C and D, figs. 26, 27, and 28, the observations obtained with small Price meter No. 363 at six-tenths depth are shown by the little squares. As a rule they fall outside the curve, meter No. 363 indicating a somewhat greater velocity than meter No. 351. This fact is also shown by the corresponding curves of figs. 16 and 17. The two sets of velocity curves (full and dotted) of fig. 28 were found from simultaneous velocity measurements. Two parties measured velocity in the same section at the same time. One party, with the Haskell meter, started near the south

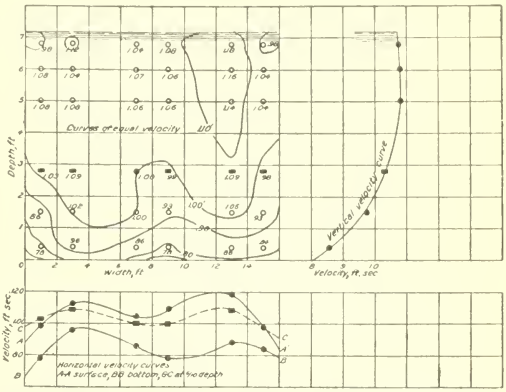


FIG. 22.—Curves of equal velocity in experiment No. 20, series D. The dots are for Haskell meter No. 3; heavy black squares for small Price meter No. 363.

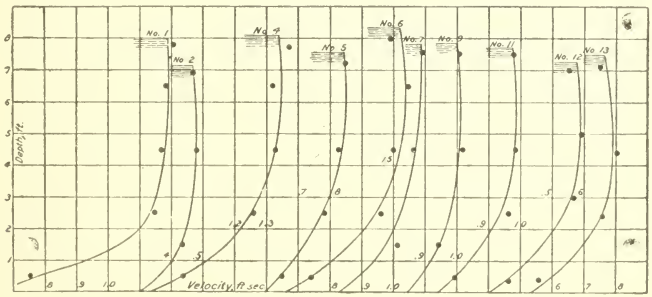


FIG. 23.—Vertical velocity curves obtained with current meters in experiments in series A. Nos. 1, 2, 8, 12, and 13 are for large Price meter No. 88; Nos. 4, 5, 6, 7, and 11 are for small Price meter No. 351.

side of the canal and worked toward the north side; the other party, with the Price meter, started at the north side and worked toward the south side. It is seen from these curves (fig. 28) that the bottom velocities agree more closely than those at the surface, and that the Haskell meter gives a much larger surface velocity than the Price meter. We should expect a little difference, since the revolving head

of the Haskell meter is larger than the wheel of the Price meter, and its center being farther below the surface it must revolve faster. But the difference in velocity is much greater than this little difference in depth of axis would indicate. (See p. 91.)

The shape of these curves evidently depends on the depth and velocity. For depths not exceeding 1 foot it is a nearly straight line,

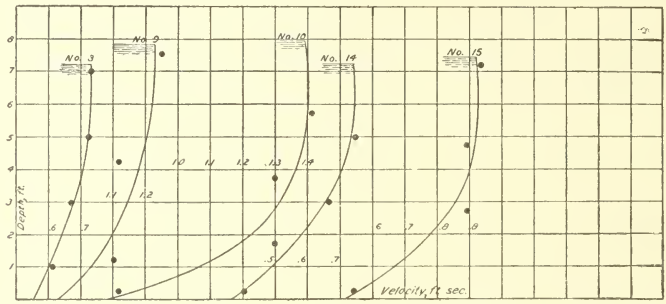


FIG. 24.—Vertical velocity curves obtained with Fteley current meter in experiments in series A.

with the maximum velocity at the surface and the mean velocity at mid depth. For depths of 8 or 9 feet and small velocities the curve is very flat, with the maximum velocity at two-tenths to three-tenths depth and the mean velocity at sixty-five-hundredths to seven-tenths depth below the surface. The radius of curvature decreases as the velocity increases. In all of these curves the least velocity is at the bottom. Nos. 6 and 8, series B, fig. 25, show the effect on the vertical

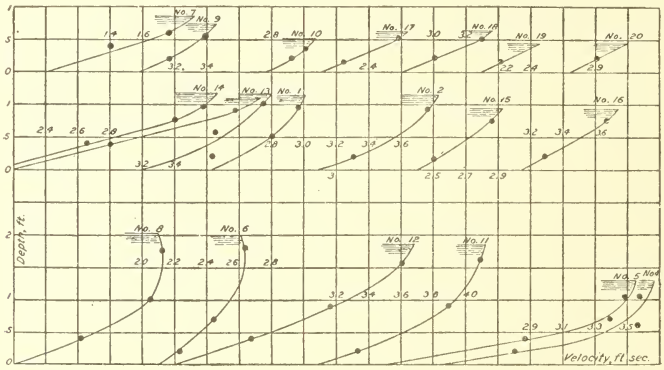


Fig. 25.—Vertical velocity curves obtained with current meters in experiments in series B. Nos. 1, 15, 17, and 19 are for small Price meter No. 351; Nos. 3, 5, 7, 8, 12, and 14 are for large Price meter No. 88; Nos. 2, 4, 6, 9, 10, 11, 13, 16, 18, and 20 are for Fteley meter.

velocity curve of checking the discharge at the lower end of the canal. For all the other curves of fig. 25 there is free discharge. The effect of checking the discharge at the lower end is to force the thread of maximum velocity from the surface to a depth of two-tenths or more. The table on page 77 gives the position of the threads of maximum and mean velocity taken from the curves shown in figs. 23 to 28. It is

difficult to locate the threads with accuracy, since very little change in the shape of the curve would make a great change in the position of the threads. It is easily seen that the shape may be changed somewhat and yet fit the observations nearly as well as the one drawn and give a discharge differing from it but little. For velocities of a foot or more per second, however, the threads can be located with a fair

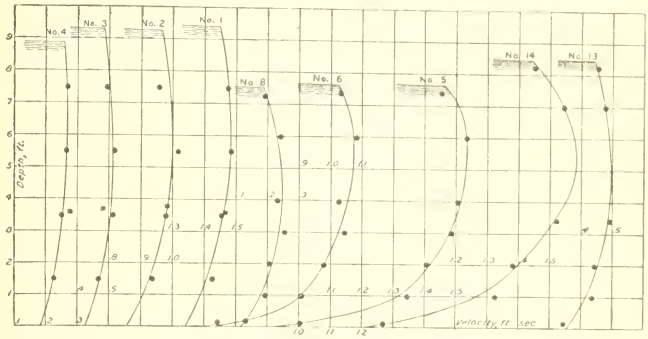


FIG. 26.—Vertical velocity curves obtained with current meters in experiments in series C. Heavy round dots are for small Price meter No. 351; the square blocks are for small Price meter No. 363.

degree of accuracy. The position of the thread of maximum velocity as found from series A is eighteen-hundredths depth below the surface; for series B it is one-tenth depth; for series C, thirty-eight-hundredths depth; and for series D, twenty-four-hundredths depth. For the mean of C and D, in which the conditions are nearly the same, it is thirty-one-hundredths depth. The position of the thread of mean

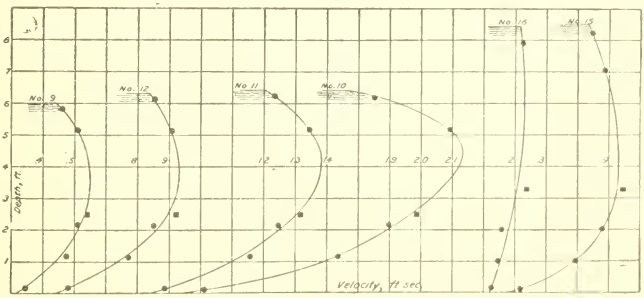


FIG. 27.—Vertical velocity curves obtained with current meters in experiments in series C. Heavy round dots are for small Price meter No. 351; the square blocks are for small Price meter No. 363.

velocity as shown by this table is sixty-six-hundredths depth for series A, fifty-four-hundredths depth for series B, and sixty-six-hundredths depth for series C and D. It is seen that the threads of mean and maximum velocity are nearer the surface in series A than in series C or D, although the depths do not differ much. This is probably due to the influence of the Croton model dam, the long upstream slope of

which has had the effect of forcing the thread of maximum velocity up to thirteen-hundredths depth. As the ratio of width to depth

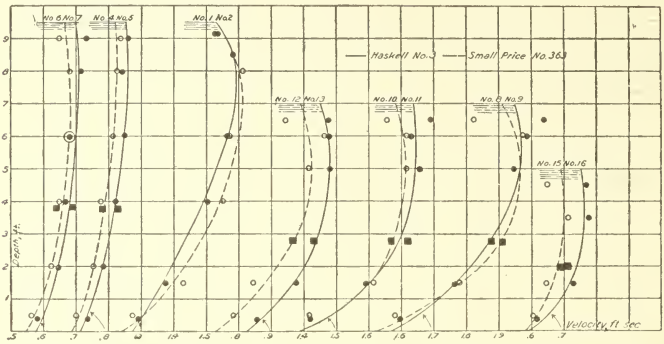


FIG. 28.—Vertical velocity curves obtained with Haskell meter No. 3 and small Price meter No. 363 in experiments in series D. Open circles are for small Price meter No. 363, point method; heavy black dots are for Haskell meter No. 3, point method; heavy black squares are for small Price meter No. 363, six-tenths-depth method.

changed from 16 to 2 the thread of mean velocity moved from fifty-four-hundredths depth to sixty-six-hundredths depth below the surface.

Table showing position of threads of maximum and mean velocity in Cornell University experiment canal as found from current-meter discharge measurements made in May, November, and December, 1900.

No. of experiment.	Series A.				Series B.				Series C.				Series D.			
	Velocity (V).	Depth (D).	Ratio $\left(\frac{dm}{D}\right)$.	Ratio $\left(\frac{d'}{D}\right)$.	Velocity (V_0).	Depth (D).	Ratio $\left(\frac{dm}{D}\right)$.	Ratio $\left(\frac{d'}{D}\right)$.	Velocity (V_0).	Depth (D).	Ratio $\left(\frac{dm}{D}\right)$.	Ratio $\left(\frac{d'}{D}\right)$.	Velocity (V_0).	Depth (D).	Ratio $\left(\frac{dm}{D}\right)$.	Ratio $\left(\frac{d'}{D}\right)$.
	Feet per second.	*Feet.*			*Feet per second.*	*Feet.*			*Feet per second.*	*Feet.*			*Feet per second.*	*Feet.*		
1	1.17	8.00	0.81	0.35	2.79	1.12	1.00	0.40	1.45	9.46	0.65	0.31	1.52	9.51	0.75	0.29
2	0.57	7.17	0.77	0.29	3.60	1.12	1.00	0.49	0.97	9.37	0.61	0.32	1.48	9.51	0.80	0.47
3	0.68	7.26	0.92	0.28	3.10	1.11	1.00	0.49	0.49	9.34	0.52	0.27	.....	9.32	.....	.....
4	1.27	8.10	0.89	0.29	3.34	1.30	1.00	0.42	0.26	8.92	0.62	0.28	0.83	9.54	0.79	0.42
5	0.84	7.54	0.80	0.49	3.09	1.30	1.00	0.38	1.45	7.67	0.70	0.33	0.79	9.54	0.84	0.42
6	1.46	8.37	0.75	0.30	2.50	2.00	0.85	0.44	1.00	7.64	0.72	0.33	0.68	9.52	0.77	0.39
7	1.06	7.85	0.84	0.45	1.54	0.79	1.00	0.45	.....	7.58	.....	.....	0.65	9.52	0.80	0.34
8	1.06	7.85	0.75	0.31	1.90	2.03	0.85	0.37	0.22	7.56	0.60	0.28	1.86	7.25	0.82	0.36
9	1.06	7.85	0.95	0.43	3.27	0.75	1.00	0.47	0.49	6.01	0.60	0.28	1.87	7.25	0.69	0.32
10	1.18	7.98	0.79	0.37	2.95	0.55	1.00	0.50	1.89	6.28	0.71	0.32	1.68	7.22	0.77	0.34
11	0.98	7.73	0.71	0.36	3.79	1.89	1.00	0.40	1.25	6.40	0.66	0.32	1.65	7.22	0.72	0.33
12	0.64	7.28	0.75	0.30	3.10	1.89	1.00	0.43	0.85	6.32	0.60	0.31	1.42	7.18	0.72	0.33
13	0.79	7.48	0.65	0.21	3.72	1.20	1.00	0.46	0.46	8.48	0.56	0.27	0.96	7.18	0.70	0.36
14	0.64	7.28	0.86	0.39	2.95	1.20	1.00	0.49	1.46	8.47	0.65	0.31	.....	7.11	.....	.....
15	0.79	7.48	0.84	0.33	2.70	0.95	1.00	0.48	0.89	8.51	0.53	0.27	0.73	5.15	0.70	0.33
16	.....	.....	.....	.....	3.47	0.95	1.00	0.48	.....	.....	0.623	0.30	0.67	5.15	0.70	0.44
17	.....	.....	.....	.....	2.43	0.69	1.00	0.50	.....	.....	0.755	0.37	.....	.....	.....	.....
18	.....	.....	.....	.....	3.14	0.69	1.00	0.50	.....	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	.....	.....	2.29	0.46	1.00	0.50	.....	.....	.....	.....	.....	.....	.....	.....
20	.....	.....	.....	.....	2.93	0.46	1.00	0.50	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	0.815	0.343	.....	.....	0.985	0.457	.....	.....	0.69	0.34	.....	.....	0.755	0.37

V = velocity found from the weir.
V_0 = velocity found with meter by ordinary method.
dm = distance above bottom to thread of maximum velocity.
d' = distance above bottom to thread of mean velocity.

The first of the following tables gives the mean, maximum, and bottom velocities in the experiments of series A, C, and D, also the ratio of bottom velocity to mean velocity and of mean velocity to mid-depth velocity. It is seen that the ratio of mean velocity to mid-depth velocity is much more nearly constant, and hence is better to use than that of mean velocity to bottom velocity. The second table gives the ratio of mean velocity to three-tenths-depth velocity, and of mean velocity to six-tenths-depth velocity in series A, C, and D. The ratio at three-tenths depth is seen to be more nearly constant than that at six-tenths depth.

Velocities at various depths and velocity ratios in Cornell University experiment canal as found from standard weir and current-meter discharge measurements.

No. of experiment.	Depth (D) in feet.	Series A. Velocities in feet per sec.* V	V_m	V_b(†)	$V_{\frac{1}{2}D}$	Ratios. $\frac{V_b}{V}$	$\frac{V}{V_{\frac{1}{2}D}}$	Depth (D) in feet.	Series C. Velocities in feet per sec.* V	V_m	V_b(†)	$V_{\frac{1}{2}D}$	Ratios. $\frac{V_b}{V}$	$\frac{V}{V_{\frac{1}{2}D}}$	Depth (D) in feet.	Series D. Velocities in feet per sec.* V	V_m	V_b(†)	$V_{\frac{1}{2}D}$	Ratios. $\frac{V_b}{V}$	$V \div V_{\frac{1}{2}D}$
1	8.00	1.17	1.26	0.80	1.24	0.69	0.90	9.46	1.41	1.45	1.05	1.44	0.74	0.98	9.51	1.53	1.62	1.29	1.57	0.84	0.97
2	7.17	0.57	0.59	0.50	0.56	0.88	0.98	9.37	0.93	0.96	0.83	0.95	0.89	0.98	9.51	1.53	1.64	1.33	1.56	0.87	0.98
3	7.26	0.68	0.76	0.60	0.70	0.88	0.97	9.34	0.48	0.50	0.43	0.50	0.89	0.96	9.32	1.54	.....	.....	.....	.....	.....
4	8.10	1.27	1.37	1.01	1.33	0.80	0.96	8.92	0.27	0.29	0.22	0.29	0.82	0.94	9.54	0.77	.....	.....	.....	.....	.....
5	7.54	0.84	0.87	0.64	0.85	0.76	0.99	7.67	1.44	1.54	1.12	1.52	0.78	0.95	9.54	0.77	.....	.....	.....	.....	.....
6	8.37	1.46	1.55	1.22	1.53	0.82	0.96	7.64	1.02	1.09	0.78	1.06	0.76	0.96	9.52	0.62	.....	.....	.....	.....	.....
7	7.85	1.06	1.10	0.92	1.08	0.87	0.98	7.58	0.59	.....	.....	.....	.....	.....	9.52	0.62	.....	.....	.....	.....	.....
8	7.85	1.06	1.09	0.92	1.07	0.87	0.99	7.56	0.26	0.29	0.15	0.28	0.58	0.93	7.25	1.91	2.01	1.65	1.96	0.86	0.97
9	7.85	1.06	1.10	0.92	1.07	0.87	0.99	6.01	0.52	0.58	0.37	0.57	0.71	0.91	7.25	1.91	2.01	1.61	1.98	0.84	0.96
10	7.98	1.18	1.24	0.83	1.20	0.70	0.98	6.28	1.94	2.17	1.42	2.07	0.73	0.94	7.22	1.65	1.77	1.42	1.69	0.85	0.98
11	7.73	0.98	1.01	0.79	1.00	0.81	0.98	6.40	1.28	1.41	0.94	1.37	0.73	0.94	7.22	1.65	1.72	1.44	1.70	0.87	0.97
12	7.28	0.64	0.71	0.49	0.70	0.77	0.92	6.32	0.89	0.98	0.63	0.96	0.71	0.93	7.18	0.96	1.01	0.80	0.99	0.83	0.97
13	7.48	0.97	0.89	0.65	0.88	0.83	0.90	8.48	0.48	0.54	0.40	0.53	0.79	0.91	7.18	0.96	1.03	0.76	1.00	0.80	0.96
14	7.28	0.64	0.73	0.42	0.68	0.66	0.94	8.47	1.45	1.60	1.04	1.58	0.72	0.92	7.11	.....	.....	.....	.....	.....	.....
15	7.48	0.79	0.87	0.56	0.85	0.71	0.93	8.51	0.92	0.95	0.67	0.95	0.73	0.97	5.15	0.69	0.71	0.59	0.68	0.86	0.99
16	.....	.....	.....	.....	.....	.....	.....	8.46	0.23	0.26	0.15	.....	0.65	.....	5.15	0.69	0.72	0.62	0.68	0.89	0.99
						0.795	0.958						0.747	0.944						0.851	0.974

* Correct velocities found from standard weir. † Velocity 2½ inches above the bottom.

NOTE.—V=mean velocity; V_m=maximum velocity; V_b=bottom velocity; $V_{\frac{1}{2}D}$=mid-depth velocity.

Velocity ratios in Cornell University experiment canal as found with current meters in May, November, and December, 1900.

No. of experiment.	Series A.				Series C.				Series D.			
	Velocity (v_0).	Depth (D).	Ratio $\left(\frac{v_0}{v_3}\right)$.	Ratio $\left(\frac{v_0}{v_6}\right)$.	Velocity (v_0).	Depth (D).	Ratio $\left(\frac{v_0}{v_3}\right)$.	Ratio $\left(\frac{v_0}{v_6}\right)$.	Velocity (v_0).	Depth (D).	Ratio $\left(\frac{v_0}{v_3}\right)$.	Ratio $\left(\frac{v_0}{v_6}\right)$.
	Ft. per sec.	*Feet.*			*Ft. per sec.*	*Feet.*			*Ft. per sec.*	*Feet.*		
1	1.10	8.00	1.082	1.050	1.45	9.46	1.022	1.009	1.52	9.51	1.059	1.012
2	0.45	7.17	1.062	1.036	0.97	9.37	1.029	1.017	1.48	9.51	1.071	1.002
3	0.68	7.26	1.066	0.997	0.49	9.34	1.037	1.022	.....	9.32	.....	.....
4	1.27	8.10	1.060	1.014	0.26	8.92	1.031	0.981	0.83	9.54	1.031	0.988
5	0.79	7.54	1.073	1.010	1.45	7.67	1.057	1.021	0.79	9.54	1.039	1.000
6	1.44	8.37	1.070	1.033	1.00	7.64	1.073	1.025	0.68	9.52	1.034	1.000
7	1.04	7.85	1.040	1.003	0.50	7.58	.....	.....	0.65	9.52	1.046	1.010
8	0.98	7.85	1.034	1.013	0.22	7.56	1.091	1.082	1.86	7.25	1.058	1.011
9	1.15	7.86	1.055	1.000	0.49	6.01	1.091	1.069	1.87	7.25	1.056	1.027
10	1.29	7.98	1.083	1.025	1.89	6.28	1.127	1.042	1.68	7.22	1.038	1.010
11	0.94	7.73	1.050	1.021	1.25	6.40	1.094	1.045	1.65	7.22	1.039	1.018
12	0.53	7.28	1.103	1.043	0.85	6.32	1.090	1.056	1.02	7.18	1.060	1.023
13	0.74	7.48	1.070	1.046	0.46	8.48	1.056	1.043	0.96	7.18	1.070	1.017
14	0.64	7.28	1.146	1.001	1.46	8.47	1.081	1.036	.....	7.11		.....
15	0.83	7.48	1.155	1.030	0.89	8.51	1.025	1.042	0.73	5.15	1.041	1.011
16	.....	.....	.....	.....	0.20	8.46	1.139	1.030	0.67	5.15	1.045	1.015
			1.077	1.021			1.069	1.035			1.048	1.010

v_0 = velocity obtained by ordinary method.
v_3 and v_6 = velocity at three-tenths and at six-tenths depth below the surface.

MEAN VELOCITY BY INTEGRATION IN VERTICALS.

The mean velocity in the discharge section was obtained by the method of integration in the eight verticals 1, 3, 5, etc., immediately after making experiments 1, 3, 9, and 37 of series E. In the following table the velocity thus obtained is compared with that obtained by the ordinary point method in the experiment just preceding:

Comparison of mean velocity obtained by the ordinary point method and by integration in verticals in Cornell University experiment canal.

Date.	Depth.	Kind of meter.	Velocity.		$\frac{V_P - V_I}{V_P}$
			Point method (V_P).	Integration method (V_I).	
1901.	*Feet.*		*Ft. per sec.*	*Ft. per sec.*	*Per cent.*
April 1	9.08	Haskell No. 3	1.468	1.460	+0.6
April 2	6.08	do	2.208	2.225	−0.8
April 5	7.41	do	1.883	1.921	−2.0
April 11	9.26	S. Price No. 351	1.522	1.568	−3.0

It will be seen that the agreement is close, the greatest difference being 3 per cent.

RATING METERS IN STILL AND IN MOVING WATER.

The results of meter and standard-weir comparisons are given in the tables on pages 64 to 67. With a few exceptions, already mentioned, these are shown graphically in figs. 16, 17, and 18, pages 68 and 69. The straight lines 0–0′ represent in each case the weir discharge and the curved lines drawn through the plotted points repre-

sent the percentage variation of the meter discharge from the corresponding weir discharge. The meter discharge is computed from a rating table prepared from ratings in still water. If we assume that the weir discharge is correct, then these curves show the percentage difference between a rating in still water and a rating in moving water, and furnish the data for preparing a rating table for moving water from the one for still water. We have only to apply the correction to any velocity for any given number of revolutions per second, shown on the proper diagram, to obtain the velocity in moving water. This has been done, and the rating tables of the meters in still and in moving water are given in the following table. The velocity in moving water for any given number of revolutions per second is greater for all speeds of the Price meters than the velocity in still water. For the Haskell meter (a propeller instrument) the velocity is less in moving water than in still water for low velocities, and probably about the same in moving water as in still water for the higher velocities.[a] The discharges might now be computed, using the rating tables for moving water, and they would agree closely with the weir discharges. New vertical velocity curves have been found for series A, and the mean velocity ascertained from them. The shape of the new curve differs little from the old one, as the range of velocities for any curve is small. The new velocities obtained from the corrected curves are given in the second column of the table.

Rating tables of current meters in still water and in moving water in Cornell University experiment canal.

Revolutions per second.	Small Price No. 351.[b]		Large Price No. 88.[b]		Haskell No. 3.[c]		Fteley.[b]		Revolutions per second.	Haskell No. 3.[c]		Fteley.[b]	
	V	Vw	V	Vw	V	Vw	V	Vw		V	Vw	V	Vw
									1.10	1.30	1.28	1.18	1.07
									1.20	1.40	1.39	1.29	1.15
0.10	0.284	0.318							1.30	1.50	1.49	1.39	1.23
0.15	0.397	0.437	0.54	0.660					1.40	1.60	1.60	1.50	1.30
0.20	0.510	0.552	0.70	0.804					1.50	1.71	1.70	1.61	1.38
0.25	0.625	0.664	0.86	0.950					1.60	1.81	1.81	1.72	1.45
0.30	0.741	0.776	1.03	1.097					1.70	1.92	1.92	1.82	1.53
0.35	0.857	0.887	1.19	1.244					1.80	2.02	2.03	1.93	1.60
0.40	0.972	0.998	1.35	1.392					1.90	2.13	2.14	2.04	1.67
0.45	1.088	1.109	1.52	1.550					2.00	2.23	2.24	2.14	1.74
0.50	1.204	1.220	1.68	1.709	0.70	0.647	0.536	0.552					
0.55	1.319	1.332	1.84	1.874	0.75	0.698	0.589	0.598					
0.60	1.435	1.447	2.01	2.042	0.80	0.751	0.643	0.644					
0.65	1.550	1.562	2.17	2.207	0.85	0.803	0.697	0.690					
0.70	1.660	1.677	2.34	2.373	0.90	0.855	0.750	0.735					
0.75	1.782	1.796	2.50	2.538	0.95	0.907	0.804	0.779					
0.80	1.897	1.915	2.66	2.702	1.00	0.960	0.858	0.822					
0.85	2.013	2.033	2.83	2.868	1.05	1.014	0.911	0.864					
0.90	2.129	2.150	2.99	3.034	1.10	1.068	0.965	0.905					
0.95	2.244	2.266	3.15	3.199	1.15	1.121	1.018	0.946					
1.00	2.36	2.38	3.32	3.366	1.20	1.174	1.072	0.987					

[a] Recent experiments with a Fteley meter do not verify this statement.

[b] Meter held with rigid rod.

[c] Meter held with cable.

NOTE.—V=velocity, in feet per second, from still-water rating; Vw=velocity, in feet per second, from moving-water rating.

A reason for the percentage increase in the variation of the meter discharge from the weir discharge as the velocity decreases is to be found in the rating table from which the velocities are computed. The experiment of November 1 shows that the small Price meter will measure a velocity of 0.23 foot per second, as the mean velocity found from the weir is 0.229 foot per second and the meter wheel revolved with regularity at all points where it was held. The observations in the rating do not extend to this velocity, however, and do not warrant the preparation of a rating table giving velocities of less than 0.5 foot per second.

In the three ratings of small Price meter No. 351 on May 9, 1901, shown in fig. 29, page 89, there are only four observations for velocities less than 0.5 foot per second and none below 0.45 foot per second. The extension of the table to velocities less than 0.5 foot per second is probably made on the assumption that this part of the rating curve is a straight line. That this is very far from the truth can be seen from an inspection of the three curves of fig. 29. Another reason is that discharge shown by the Cornell University standard weir is probably from 1 to 3 per cent too large for low heads on the weir. Recent experiments seem to indicate this fact. These two causes, however, account for only a comparatively small part of the difference between current-meter and weir discharge at low velocities which the experiments of series A and C, and others made since the writing of the body of this paper, indicate. The failure of the meter to indicate as high a velocity when held in a very slow-moving current, as when the meter is dragged through still water in the direction of the current, is probably due to the stream lines becoming more and more oblique to the axis of the canal as the velocity decreases, and consequently their impact on the meter being less than when they moved more nearly in the direction of the axis of the canal.

ERROR IN USING AVERAGE OF BOTTOM AND SURFACE VELOCITIES FOR MEAN VELOCITY.

The following table gives the mean velocity and the average of the velocities 0.5 foot above the bottom and 0.5 foot below the surface for the experiments of series A, C, and D; also the error, in per cent, made by using the average of surface and bottom velocities instead of the mean velocity. It is seen that in all these experiments except two the mean velocity is greater than the half sum of the surface and bottom velocities, the difference varying from — 2.2 per cent to + 30.6 per cent.

Table showing relation between mean velocity and average of surface and bottom velocities as found from Cornell University standard weir and from current meters in Cornell experiment canal.

No. of experiment.	Series A.			Series C.			Series D.		
	V	V'	$\frac{V-V'}{V}$	V	V'	$\frac{V-V'}{V}$	V	V'	$\frac{V-V'}{V}$
	Feet per second.	*Feet per second.*	*Per cent.*	*Feet per second.*	*Feet per second.*	*Per cent.*	*Feet per second.*	*Feet per second.*	*Per cent.*
1	1.164	0.987	+15.3	1.409	1.412	−0.2	1.528	1.436	+6.2
2	0.573	0.416	+27.5	0.932	0.954	−0.2	1.528	1.436	+6.2
3	.....	.....	.....	0.477	0.468	+0.2	.....	.....	.....
4	1.268	1.190	+6.1	0.265	0.231	+12.8	.....	.....	.....
5	0.841	0.749	+10.9	1.444	1.364	+5.6	.....	.....	.....
6	1.462	1.384	+5.4	1.018	0.940	+7.7	.....	.....	.....
7	1.056	0.965	+8.6	0.502	.....	.....	.....	.....	.....
8	1.056	0.946	+10.4	0.255	0.177	+30.6	1.905	1.807	+5.2
9	.....	.....	.....	0.515	0.435	+15.5	1.905	1.779	+6.6
10	.....	.....	.....	1.914	1.730	+9.6	1.649	1.613	+2.2
11	0.980	0.887	+9.5	1.283	1.129	+12.0	1.649	1.590	+3.6
12	0.643	0.476	+25.9	0.893	0.759	+15.0	0.955	0.973	−1.9
13	0.788	0.687	+12.7	0.478	0.422	+11.8	0.955	0.897	+6.1
14	.....	.....	.....	1.454	1.311	+9.8	.....	.....	.....
15	.....	.....	.....	0.915	0.784	+14.3	0.689	0.704	−2.2
16	.....	.....	.....	0.229	0.179	+21.8	0.689	0.659	+4.3

V = mean velocity found from standard weir.

V' = mean of velocities 0.5 foot above bottom and 0.5 foot below surface, as found by meters, uncorrected.

From the foregoing table, and from the table on page 79, in which is given the ratio of bottom velocity to mean velocity, it appears that bottom velocity is not a desirable quantity to use in computing discharge, for it varies between too wide limits. In a stream with a stony or gravelly bottom the limits must be considerably greater than in the Cornell canal with its smooth bottom. Observations at mid depth or at six-tenths depth give better results.

COMPARISON OF RESULTS BY THREE METHODS OF OPERATING METER.

Three methods of operating meters have been used in these experiments, viz, the ordinary method, the six-tenths-depth, and the integration. A detailed account of the manner of operating the meter by each of these methods has been given on pages 62 to 63. The time required to make a discharge measurement was from thirty to sixty minutes with the ordinary method, from twenty to thirty minutes with the six-tenths-depth, and from five to ten minutes with the integration.

The results by the ordinary method in series A to D (fig. 16, p. 68) give for each meter a well-defined line which agrees with the weir line (0–0′) within about 2 per cent for velocities greater than 1.5 feet per second, the meter discharge being less than the corresponding weir discharge.

The agreement with the weir discharge is closer in series E than in series A to D, being −0.03 per cent for the Haskell meter, −1.13 per cent for Price meter No. 363, and −1.88 per cent for Price meter No. 351. The results by the six-tenths-depth method do not give as well

defined a line (fig. 17) for each meter as do those by the ordinary method, the meter discharge being from 1 to 6 per cent greater than the corresponding weir discharge, and the mean being 3.5 per cent for small Price meter No. 363. If the observations with the latter meter had been taken at sixty-four-hundredths depth instead of at six-tenths depth the line representing the mean would coincide with the weir line 0–0′, and the greatest percentage variations from the mean would be −2.5 per cent and +2.5 per cent.

The results by the integration method do not give a well-defined line. The meter discharge is from 1 per cent to 9 per cent greater than the weir discharge for velocities greater than 0.5 foot per second in the experiments of series C and D, and from 0 to 5 per cent less than the weir discharge for the experiments of series A. The following table gives the true velocity as found from the weir and the velocity found by the integration method for different speeds of the meter, also the ratio of difference between these velocities and the true velocity, expressed in per cent:

Table showing effect of variation of speed of meter in integration method.

No. of experiment.	Date.	Depth.	True velocity by weir (V) per second.	Speed of meter per second.	Velocity of water by meter (V_1) per second.	$\frac{V-V_1}{V}$	Kind of meter.
	1900.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Per cent.*	([a])
1	May 8	8.10	1.268	0.101	1.268	0.00	S.P.351.
2	do	8.10	1.268	0.152	1.235	+ 2.60	Do.
3	do	8.10	1.268	0.270	1.200	+ 5.35	Do.
4	do	7.54	0.841	0.079	0.834	+ 0.09	Fteley.
5	do	7.54	0.841	0.055	0.842	− 0.01	Do.
6	May 9	7.85	1.056	0.056	1.028	+ 2.65	S.P.351.
7	do	7.85	1.056	0.043	1.008	+ 4.54	L.P.88.
8	May 15	7.73	0.980	0.032	0.978	+ 0.02	S.P.351.
9	October 24	9.46	1.409	0.118	1.429	− 1.42	S.P.363.
10	do	9.37	0.932	0.142	0.982	− 5.36	Do.
11	do	9.34	0.477	0.164	0.485	− 1.68	Do.
12	do	8.92	0.265	0.107	0.308	−16.23	Do.
13	October 26	7.67	1.444	0.137	1.519	− 5.20	Do.
14	do	7.64	1.[illegible]	0.135	1.079	− 5.99	Do.
15	October 27	7.58	0.5[illegible]	0.143	0.522	− 3.99	Do.
16	do	7.56	0.255	0.128	0.312	−22.35	Do.
17	do	6.01	0.515	0.142	0.555	− 7.77	Do.
18	do	6.28	1.940	0.180	2.030	− 4.64	Do.
19	do	6.40	1.283	0.154	1.338	− 4.29	Do.
20	do	6.32	0.893	0.188	0.920	− 3.02	Do.
21	October 29	8.48	0.478	0.151	0.492	− 2.93	Do.
22	October 31	8.47	1.454	0.293	1.552	− 6.74	Do.
23	do	8.51	0.915	0.258	1.002	− 9.51	Do.
24	November 1	8.46	0.229	0.185	0.319	−39.30	Do.
25	December 6	9.51	1.528	0.253	1.540	− 0.78	Do.
26	do	9.51	1.528	0.284	1.572	− 2.87	Hask. 3.
27	December 7	9.32	1.535	0.243	1.576	− 2.66	Do.
28	December 8	7.25	1.905	0.252	1.962	− 2.99	Do.
29	do	7.22	1.649	0.295	1.748	− 6.00	Do.
30	do	7.18	0.955	0.254	1.039	− 8.79	Do.
31	do	5.15	0.689	0.179	0.752	− 9.14	Do.

[a] S. P. = small Price; L. P. = large Price; Hask. = Haskell. Figures given are the numbers of the meters.

Table showing effect of speed of meter on observed velocity as found by the integration method in experiments of table on page 84.

Experiments Nos. 9 to 25, omitting Nos. 12, 16, and 24.						Experiments Nos. 1 to 8.			
Speed of meter 0.10 to 0.14.	$\frac{V-V_1}{V}$	Speed of meter 0.14 to 0.18.	$\frac{V-V_1}{V}$	Speed of meter 0.18 to 0.30.	$\frac{V-V_1}{V}$	Speed of meter 0.05 to 0.15.	$\frac{V-V_1}{V}$	Speed of meter 0.15 to 0.30.	$\frac{V-V_1}{V}$
Feet per second.	*Per cent.*	*Feet per second.*	*Per cent.*	*Feet per second.*	*Per cent.*	*Feet per second.*	*Per cent.*	*Feet per second.*	*Per cent.*
0.118	−1.42	0.142	−5.36	0.180	−4.64	0.056	+2.65	0.152	+2.60
0.137	−5.20	0.164	−1.68	0.188	−3.02	0.043	+4.54	0.270	+5.35
0.135	−5.99	0.143	−3.99	0.293	−6.74	0.032	+0.02	.....	.....
0.130	−4.20	0.142	−7.77	0.258	−9.51	0.101	+0.00	.....	.....
.....	.....	0.154	−4.29	0.253	−0.78	0.079	+0.09	.....	.....
.....	.....	0.151	−2.93	0.234	−4.94	0.055	−0.01	.....	.....
.....	.....	0.159	−6.33	.....	.....	0.061	+1.22	0.211	+3.97

This ratio is positive for all the experiments of series A and is negative for those of C and D. This difference of sign is due to two causes: (1) The meter was moved faster in the experiments of C and D than in those of series A; and (2) it was moved through only 14 feet of the width in series C and D and through nearly 15.5 feet of the width in series A, and the additional 1.5 feet of width had a small velocity. It is seen from the above table that for low velocities the error in velocity increases as the speed of the meter increases. The table on page 84 shows this effect for velocities from 0.5 foot to 2 feet per second.

COMPARISON OF RESULTS OBTAINED IN 1900 WITH THOSE OBTAINED IN 1901.

Examining the plotted results in figs. 16 (page 68) and 18 (page 69), it is seen that the meter discharge, compared with the corresponding weir discharge, is somewhat larger for the work of 1901 than for that of 1900 for velocities greater than 1.4 feet per second. This can not be due to change in rating of the meters, for an increase in the friction in a meter would reduce the observed velocity and make the meter discharge too small. There was considerably more seepage into the canal when the experiments of series E (1901) were made than at the time those of A, B, C, and D (1900) were made. There was also quite a little surface water entering the canal between the weir and the meter section in the experiments of series E. It is hardly possible, however, that this inflow between the weir and the meter section could amount to 2 per cent of the canal discharge. It must be borne in mind in this connection that the discharges obtained in 1900 for velocities greater than 1.4 feet were in shallow water, and therefore are not so reliable as those obtained in series E.

EFFECT OF METHOD OF HOLDING METER IN WATER.

In some of the experiments the meter was suspended from a cable; in others it was held in the water with a rigid rod. In the latter cases its axis was free to move about a horizontal axis; in the former cases

it was free to move about a vertical as well as a horizontal axis. When used with a cable a sinker is necessary, which, being attached to the under side of the meter, keeps the axis of the revolving wheel farther from the bottom than is desirable in some cases. It is also difficult to keep the meter in any desired place when held with a cable, and it usually changes its position considerably in a swift current. It was in order to measure the velocity close to the bottom and keep the meter at a desired place during the observation that in many of the experiments the meter was held with a rod. In ordinary river gaging, however, the Price and Haskell meters are held with cables and the meters are rated in still water suspended from a car and cable. The question then arose: "Is the rating table for a meter used suspended from a cable applicable to the same meter held with a rigid rod?"

On December 30, 1900, Mr. E. G. Paul made two ratings of small Price meter No. 351 in still water, one with the meter held with a rigid rod and the other with the meter held with a cable and a 5-pound lead sinker. In the following tables (pp. 87 and 88) are given the observations and computations of these ratings. The second column ("time in seconds") gives the average time required for the car to which the meter was attached to move over a run of 100 feet, and again over the same course in the opposite direction; the third column gives the number of revolutions observed in this average time; the seventh column gives for each of these cases the difference between the observed velocity and the velocity computed from the old rating table of April 23, 1900, for the same meter held with a cable. The tenth column of the first table (p. 87) gives the difference between the observed velocities and those computed from the new rating table, which is based on meter rated in still water and held by a rigid rod. The portion of this new rating table which was used in reducing the Cornell experiments is given on page 81. By comparing the corresponding quantities in the seventh and tenth columns of this table it will be seen how much more closely the values in the new rating table fit the observations than do those of the old one. The tenth column shows also how much the relation between the revolutions per second of this meter and the velocity as shown by these observations differs from the "most probable" straight line, $y=0.047+2.313x$, y being velocity in feet per second and x revolutions of meter wheel per second. From the seventh column of the table on page 87 it is seen that the observed velocities are larger than the computed velocities, indicating more friction in the meter on December 30, 1900, than on April 23, 1900.

The "most probable" linear relation between x and y for this case of the meter held with a cable was found to be $y=0.067+2.321x$. The differences in the tenth column show that this line does not fit the observations. It crosses the curve given by the observations twice as

y increases from 1 to 8 feet per second. The rating table was prepared by using this line as a basis, applying corrections as indicated by the corresponding difference of the tenth column, and also that the rating table will difference smoothly. The numbers in column 12 show how closely the observed velocities agree with those computed from the new rating table with the meter held with a cable.

It should be noted that the smallest observed velocity is about 0.5 foot per second in one case and 0.35 foot in the other case.

Observations and computations of a rating of small Price meter No. 351 held by rigid rod, made at Chevy Chase, Md., December 30, 1900.

1.	2 and 3.		4.	5.	6.	7.	8.	9.	10.	11.
No. of observation.	Length of run, 100 feet.		Revolutions per second (x).	Observed velocity (y).	Computed velocity (y^1).[a]	Difference ($y-y^1$).	x^2	xy	Residual (v).	v^2
	Time.	Revolutions of meter.								
	Seconds.			*Feet per second.*	*Feet per second.*	*Ft. per second.*				
1	9.25	43.00	4.648	10.811	10.815	−.004	21.604	50.245	+.059	.003481
2	10.5	42.50	[b]4.048	[b]9.524	9.405	+.119				
3	16.0	43.00	2.688	6.250	6.231	+.019	7.225	16.800	.014	.000196
4	22.5	43.00	1.911	4.444	4.414	+.030	3.652	8.493	.022	.000484
5	35.0	42.25	1.207	2.857	2.797	+.060	1.457	3.448	+.018	.000324
6	45.0	42.00	0.933	2.222	2.183	+.039	0.870	2.073	+.017	.000289
7	53.0	42.00	0.794	1.887	1.867	+.020	0.630	1.498	+.003	.000009
8	54.5	42.00	0.774	1.835	1.823	+.012	0.599	1.420	.003	.000009
9	68.0	41.75	0.614	1.471	1.461	+.010	0.377	0.903	+.004	.000016
10	85.5	41.75	0.488	1.170	1.174	.004	0.238	0.571	.006	.000036
11	106.5	41.00	0.385	0.939	0.944	−.005	0.148	0.362	+.001	.000001
12	113.0	41.00	0.363	0.885	0.891	−.006	0.132	0.321	−.002	.000004
13	154.0	40.50	0.263	0.649	0.669	−.020	0.069	0.171	.006	.000036
14	197.0	39.50	0.201	0.508	0.522	.014	0.040	0.102	.004	.000016
15	220.0	39.00	0.177	0.455	0.569	.014	0.031	0.081	.001	.000001
16	293.0	36.90	0.126	0.341	0.351	−.010	0.016	0.043	.003	.000009
			15.572	36.724			37.088	86.531		.004911

[a] Computed from rating table prepared from rating of April 23, 1900.

[b] Omitted in computing Σx and Σy.

NOTE.—Observation equation, $y-a-bx=v$; normal equations, $a\Sigma x+b\Sigma x^2=\Sigma xy$, $na+b\Sigma x=\Sigma y$. For these observations these become $15.572\,a+37.088\,b=86.531$, $15\,a+15.572\,b=36.724$. The solution of these gives $b=2.313$ and $a=.047$. The mean error of a single observation is $\sqrt{\frac{\Sigma v^2}{n-1}}=.019$. The probable error of result is $.6745\sqrt{\frac{\Sigma v^2}{n(n-1)}}=.003$.

Observations and computations of a rating of small Price meter No. 351 held by cable, made at Chevy Chase, Md., December 30, 1900.

1.	2 and 3.		4.	5.	6.	7.	8.	9.	10.	11.	12.
No. of observation.	Length of run, 100 feet.		Revolutions per second (x).	Observed velocity (y).	Computed velocity (y').[a]	Difference ($y-y'$).	x^2	xy	Residual (v).	Computed velocity (y'').[b]	Difference ($y-y''$).
	Time.	Revolutions of meter.									
	Seconds.			*Ft. per second.*	*Ft. per second.*	*Ft. per second.*				*Ft. per second.*	
1	10.5	42.06	4.000	9.524	9.300	+.224					
2	12.5	42.50	3.400	8.000	7.900	+.100	11.560	27.200	+.042	7.98	+.02
3	16.5	42.50	2.576	6.061	5.967	+.094	6.636	15.613	+.015	6.04	+.021
4	21.5	42.75	1.990	4.651	4.588	+.063	3.960	9.256	−.034	4.68	−.029
5	26.0	42.50	1.635	3.846	3.767	+.079	2.673	6.288	−.015	3.837	+.009
6	29.0	42.50	1.465	3.448	3.383	+.065	2.146	5.051	−.020	3.443	+.005
7	31.0	42.25	1.363	3.226	3.151	+.075	1.858	4.397	−.004	3.290	+.017
8	41.0	42.50	1.037	2.439	2.411	+.028	1.075	2.529	−.034	2.451	−.012
9	50.0	42.50	0.850	2.000	1.990	+.010	0.723	1.700	−.039	2.024	−.024
10	61.0	42.00	0.688	1.639	1.624	+.015	0.473	1.128	−.024	1.655	−.016
11	70.0	42.00	0.600	1.429	1.430	−.001	0.360	0.857	.030	1.454	−.025
12	80.5	41.25	0.512	1.242	1.226	+.016	0.262	0.636	−.013	1.256	−.014
13	90.5	40.00	0.442	1.105	1.072	+.033	0.195	0.488	+.012	1.098	+.007
14	105.5	39.00	0.370	0.949	0.908	+.041	0.137	0.351	+.024	0.938	+.011
15	125.0	38.00	0.304	0.800	0.759	+.041	0.092	0.243	+.028	0.790	+.010
16	140.0	37.00	0.264	0.714	0.671	+.043	0.070	0.189	+.035	0.697	+.017
17	171.0	36.00	0.215	0.585	0.556	+.029	0.046	0.126	+.019	0.585	−.000
18	184.0	36.00	0.196	0.543	0.507	+.036	0.038	0.106	+.022	0.541	+.002
19	211.0	35.75	0.169	0.474	0.452	+.022	0.029	0.080	+.015	0.479	−.005
			18.076	43.151			32.334	76.239			

[a] Computed from rating of April 23, 1900.

[b] Computed from rating of December 30, 1900.

NOTE.—Most probable straight line given by these observations, $y=.067+2.321x$.

The following table shows the percentage difference of velocity for each 0.05 revolution for these two ways of holding the meter. It is seen that a given number of revolutions per second of this meter indicates a higher velocity when it is held with a cable than when it is held with a rigid rod, and that this percentage difference decreases as the velocity increases. In other words, in a given velocity the meter will revolve faster when held with a rigid rod than when held with a cable. It must be remembered that the values given in this table for velocities less than about 0.5 foot per second are only approximate, since the observations do not extend below 0.35 foot per second. We may say that if the rating table for this meter held with a cable be used to reduce observations made with the meter held with a rigid rod, the results will be in error from 1.3 per cent to 8.5 per cent for velocities from 1.5 feet to 0.5 foot per second.

Table showing percentage difference in velocity as shown by small Price meter No. 351 when rated in still water on a rigid rod and on a cable.

Speed of meter.	V_r	V_c	$\frac{V_r - V_c}{V_r}$	Speed of meter.	V_r	V_c	$\frac{V_r - V_c}{V_r}$
R. per sec.	*F. per sec.*	*F. per sec.*	*Per cent.*	*R. per sec.*	*F. per sec.*	*F. per sec.*	*Per cent.*
0.15	0.397	0.433	9.1	0.60	1.435	1.455	1.4
0.20	0.510	0.550	7.8	0.65	1.550	1.568	1.2
0.25	0.625	0.666	6.6	0.70	1.666	1.682	1.0
0.30	0.741	0.781	5.4	0.75	1.782	1.796	0.8
0.35	0.857	0.894	4.3	0.80	1.897	1.910	0.7
0.40	0.972	1.006	3.5	0.85	2.013	2.024	0.5
0.45	1.088	1.118	2.8	0.90	2.129	2.138	0.4
0.50	1.204	1.230	2.2	0.95	2.244	2.252	0.4
0.55	1.319	1.342	1.7	1.00	2.36	2.37	0.3

V_r = velocity with meter rated on a rigid rod.
V_c = velocity with meter rated on a cable.

Small Price meter No. 351 was again rated three times on May 9, 1901. It was held (1) with a cable, using an 18-pound sinker; (2) with a rod, the meter being free to tip; and (3) with a rod and the meter not free to tip. Space will not permit the insertion of the observed data or the computations, but the results are plotted in fig. 29, using R= revolutions per second as abscissæ and $K=\frac{V}{R}$=ratio of velocity to revolutions as ordinates. It is seen that these rating observations give a separate curve for each of these cases. The value of K for any value of R for one curve is very different from that for the other curves for velocities less than about 3 feet per second. For example, for R=0.3, K=2.755 for case 1 (curve AE), 2.585 for case 2 (curve BE), and 2.485 for case 3 (curve DF). The coefficient is largest when the meter has the most freedom of motion and least when it has no freedom of motion. As the velocity for a given number of revolutions varies directly with K, the velocity decreases as the freedom to tip about a horizontal axis and to swing around a vertical axis decreases. Or, stated in the other way, in a current of a given velocity the revolutions increase as the freedom of motion decreases. Each of these cases therefore requires a separate rating table.

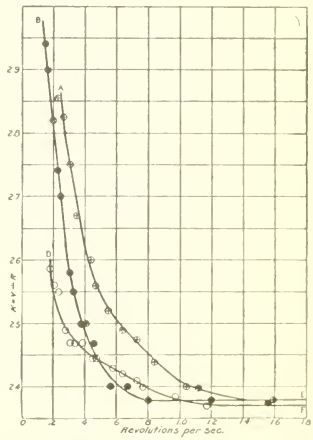


FIG. 29.—Curves showing relation between revolutions of meter and ratio between velocity of water and revolutions of meter from three ratings of small Price meter No. 351 at Chevy Chase, Md., May 9, 1901. Crossed circles are for observations with meter held with cable, an 18-pound sinker being used. Heavy black dots are for observations with meter held with rod and free to tip. Open circles are for observations with meter held with rod and not free to tip.

SURFACE VELOCITY EXPERIMENTS WITH FLOAT RODS AND WITH CURRENT METERS.

It was noticed during the weir and current-meter comparisons that the shape of the vertical velocity curve near the surface obtained with

a small Price meter was quite different under certain conditions from that obtained with the Haskell meter under the same conditions. This peculiarity can be seen in the simultaneously obtained curves of fig. 30. The Haskell meter indicates a higher surface velocity than the Price meter. By surface velocity obtained with a meter is meant that obtained when the revolving part of the meter is entirely under water all of the time and yet as close to the surface as possible. For the three meters used in these surface velocity observations the distance of the center below the surface was as follows: Small Price meter No. 351, from 2.5 to 3 inches; Fteley No. 107, from 3 to 3.5 inches; Haskell No. 3, from 4 to 4.5 inches.

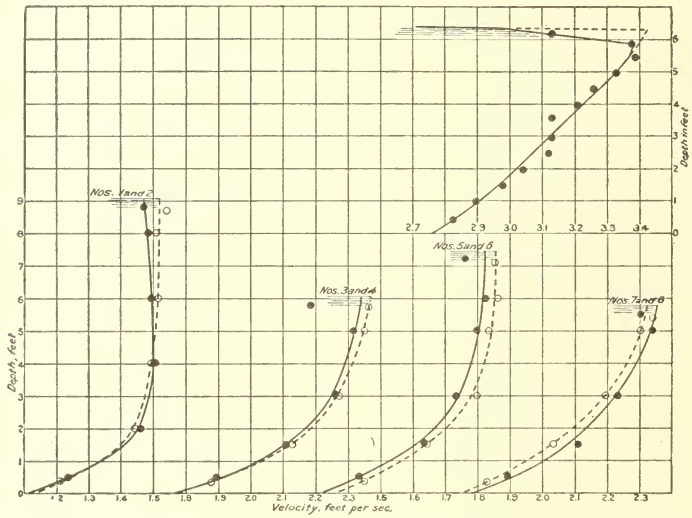


FIG. 30.—Vertical velocity curves from simultaneous experiments of series E with small Price meter No. 363 and with Haskell meter No. 3. Large black dots are for Price meter, open circles for Haskell meter.

In order to investigate this matter further the surface velocity of a part of the canal was measured simultaneously with floats and with two current meters. The floats used were 6-inch cubes of wood loaded with lead so as to have an immersion of $5\frac{1}{4}$ inches. Surface floats of wood 6 inches by 6 inches by 1 inch thick were also used. These were started near the center of the canal 18 feet above the upper wire and timed over a run of 60 feet. Any that passed the lower wire within 2 feet of either side were not used in computing velocity. The meters were held 10 feet below the lower wire, the Haskell at 5 and 7 feet from the south side of the canal, the Price at 9 and 11 feet from the south side, and the revolutions were counted for periods of forty seconds. The results of the experiments are given in the following table:

Comparison of surface velocity measured with float rods and with current meters.

Small Price meter No. 351.				Haskell meter No. 3.			
Number of float observations.	Velocity with floats.	Number of 40-second periods.	Velocity with meter.	Number of float observations.	Velocity with floats.	Number of 40-second periods.	Velocity with meter.
	Feet per second.		*Feet per second.*		*Feet per second.*		*Feet per second.*
11	3.122	10	2.794	13	3.083	13	3.171
12	3.076	12	2.806	12	3.144	12	3.187
13	3.030	13	2.818	10	3.135	10	3.165
36	3.076	35	2.806	35	3.121	35	3.174

During the foregoing observations the depth of water in canal was 6.04 feet, its mean velocity 2.8 feet, and the discharge 275.3 cubic feet per second. The float velocity that is compared with the Price meter velocity is obtained from the floats passing the lower wire from 2 to 8 feet from the south side of canal; that which is compared with the Haskell meter velocity is found from the floats passing the lower wire from 8 to 14 feet from the south side of canal. It is seen that in each experiment the float velocity is greater than that of the Price meter and less than that of the Haskell meter. The mean float velocity for the three experiments is 8.8 per cent greater than the velocity with the Price meter and 1.7 per cent less than that with the Haskell meter.

It was thought that possibly this failure of the small Price meter to give correct surface velocity indications was due to wave motion of the meter. Another experiment was therefore made with the floats and with the meter held with a rod and not free to tip. Fteley electric meter No. 107 was also used in place of the Haskell meter. The floats were started at many points in the width of the canal and were timed over a run of 50 feet. Those that came within 2 feet of either bank were not used in computing the velocity. The meters were held 24 feet below the lower wire at points from 0 to 7 feet from the center, and the revolutions were counted for 50-second periods.

The mean surface velocity shown by the small Price meter from thirty-two 50-second periods is 1.967 feet, and the corresponding float velocity obtained from ten floats passing from 2 to 8 feet from the south side of canal is 2.146 feet. The corresponding surface velocity shown by the Fteley meter is 2.074 feet, and by the floats from 8 to 14 feet from the south side of canal, 2.137 feet. The float velocity is 8.3 per cent greater than the Price meter velocity and 2.95 per cent greater than the Fteley meter velocity. The difference between the float and the Price meter velocities is about the same as in the previous experiments.

During this experiment the Price meter was held 3.5 feet from the south side of canal, with its center $2\frac{3}{4}$ inches below the surface for seven 50-second periods, and again with its center 4.5 inches below

the surface for about the same length of time. The mean velocity at $2\frac{3}{4}$ inches depth was 1.884 feet, and at 4.5 inches depth it was 2.035 feet. The float velocity at this point was 2.137 feet. The indicated velocity increased 7.4 per cent as the meter was lowered $1\frac{3}{4}$ inches. The float work in this experiment is not very satisfactory.

On May 20 vertical velocity-curve data were taken with small Price meter No. 351 and with Haskell meter No. 3 for different mean velocities, with a view to determining the magnitude of this error at different velocities and depths below the surface. The Haskell meter was held with a cable 1 foot south of the center of the canal and 244 feet from the weir; the Price meter was held with a cable 1 foot north of the center of canal. The following data were obtained:

Velocities near the surface of Cornell University experiment canal as found with small Price meter No. 351 and with Haskell meter No. 3.

Number of run.	Small Price meter No. 351.[a]				Haskell meter No. 3.[b]		
	Depth below surface, in inches.				Depth below surface, in inches.		
	2.5	4.5	6.5	8.5	4.5	6.5	8.5.
Second	0.482	0.490	0.482	.....	0	0	0
Third	0.556	0.595	0.575	.....	0.592	0.615	0.602
Fourth	0.936	0.958	0.958	0.942	1.015	1.032	1.010
Fifth	1.297	1.281	1.320	1.299	1.348	1.325	.....
Sixth	1.480	1.457	1.389	1.434	1.450	1.392	1.412
Seventh	1.611	1.556	1.533	.....	1.552	1.572	.....

[a] Meter held with cable 1 foot north of canal center and 244 feet from weir.
[b] Meter held with cable 1 foot south of canal center and 244 feet from weir.

Each run lasted about half an hour, during which time the mean velocity remained constant. These results indicate that for velocities less than 1.5 feet the difference between the velocities indicated by these meters is small from the surface to a depth of 8.5 inches.

In the upper right-hand corner of fig. 30 is a vertical velocity curve prepared from thirty-five 50-second observations taken in forty minutes 7 feet from the south side of the canal, at a station 220 feet from the weir, with small Price meter No. 351. It shows a decrease of 8.5 per cent in the velocity $2\frac{3}{4}$ inches below the surface.

From these float and current-meter surface velocity experiments we conclude that a small Price meter will not measure velocity correctly when its center is within 0.5 foot of the surface, if the velocity be greater than 1.5 feet per second, and that this error increases from 0 at about 0.5 foot below the surface to 8 or 9 per cent at 2.5 inches below the surface.

APPLICATION OF RESULTS TO ORDINARY RIVER GAGING.

It has been shown that the discharge of the Cornell University canal can be measured with a small Price current meter by the ordinary point method with an error of not more than 1 per cent under favorable conditions. This degree of accuracy, however, can seldom

be attained in ordinary river gaging, as the conditions are not so favorable for accurate work. The bed of the Cornell canal is hard, smooth, and regular in shape; the bed of a river is frequently of soft material, into which the meter will settle, or is gravelly, stony, and irregular in shape. There are no shallow parts in the canal, the depth and velocity of which it is difficult to measure with accuracy, but frequently there are one or more of these in a river discharge section. There is a good measurable velocity in all parts of the canal for all depths, while in a river there are frequently parts in which the velocity is too small for accurate measurement. The change in velocity from one point to another in a discharge section is frequently greater in a river than in the canal, on account of obstructions. Fluctuations of the surface elevation are also larger in a river than in the canal. On these accounts it is to be expected that ordinary river discharge measurements may be several per cent less accurate than those of this canal.

In river gaging work, however, it is not alone accurate discharge measurements that are required, but it is the accurate measurement of the volume passing the gaging station each day and each month. The accuracy of daily and monthly flow of a stream depends on the accuracy of the discharge curve, or the relation between the total discharge and the river stage, and on the accuracy of measurement of the fluctuation of river stage. The latter is quite as important as the former, and improvement in it should keep pace with improvements in the former.

ACCURACY OF RESULTS.

The discharge of the Cornell University standard weir is computed from Bazin's formula. It is not possible, however, to measure the head on the weir in exactly the same way that Bazin measured the head on his weir, so that this formula is not strictly applicable to this weir. From experiments made at the Cornell hydraulic laboratory, however, Prof. G. S. Williams believes that the actual discharge of the Cornell weir will not differ from that computed by Bazin's formula by more than 1 per cent for heads up to 1.5 feet, nor more than 3 per cent for heads up to 2.5 feet.

The results given in the tables have been obtained with five current meters operated in three ways by several observers. In several of the experiments simultaneous measurements were made with two meters, so that we have several checks on the work. We have not carried any of the computations beyond the third decimal place, believing that the length of a meter observation, the method of obtaining fractional parts of a revolution of the meter wheel, the uncertainty in the exact location of the vertical velocity curve, and the pulsations in the water do not warrant even this degree of accuracy. In closely studying the results some little inaccuracies will be found, as all the results are not obtained in exactly the same way; but they are believed to be substantially correct.

In comparing the results of these experiments with results obtained by other experimenters it must be remembered that we have used smaller velocities in many of our experiments than were used by them. In Fteley and Stearns's comparisons (p. 57) the smallest mean velocity is 1.7 feet, in Henry's (p. 50) the smallest is 3 feet, in Bazin's (p. 43) the smallest is 1.25 feet, in Francis's (p. 53) it is 0.5 foot, and in Marr's (p. 48) 2.4 feet. For these and higher velocities our meter results by the ordinary method agree closely with those given by the weir. We are unable to find any comparisons by other experimenters for velocities less than 1 foot per second, except a few by Francis with rods and those at Cornell with rods (p. 51). The large disagreement between meter and weir is for the low velocities, a field into which apparently few experimenters have entered.

CONCLUSIONS.

The conclusions to be drawn from these experiments may be briefly summarized as follows:

(1) Discharge measured with current meter by the ordinary (point) method agrees with that given by the Cornell standard weir within 2 per cent for velocities above 1.5 feet per second. (See tables on pages 64 to 67 and 70.)

(2) For velocities less than 1.5 feet per second the discharge found with the Price meters is less than the corresponding weir discharge, and the difference increases rapidly as the velocity decreases. (See tables on pages 64 to 67.)

(3) For velocities less than about 1.5 feet per second the discharge found with the Haskell meter is greater than that of the weir, and the difference increases as the velocity decreases. This difference is 6 per cent for a velocity of 0.75 foot per second. (See fig. 16.)

(4) The discharge of the Cornell canal can be measured with a small Price meter, ordinary point method, with an error of not more than 1 per cent under favorable conditions, a velocity observation lasting fifty seconds being taken in each 2.3 square feet of discharge area.

(5) When the most accurate results are desired the meter should be held with a rod and not given freedom to tip.

(6) Velocities of 1.5 feet per second and upward obtained with a small Price meter when its center is closer to the surface than 0.5 foot are too small by from 0 to 9 per cent. This error, however, decreases from maximum at the surface to 0 at about 0.5 foot depth.

(7) The small Price meter will measure velocities of 1 foot per second and less more accurately than either the large Price meter or the Haskell meter. It appears from these experiments that the smallest velocity that these meters will measure with a fair degree of accuracy is 0.5 foot for the large Price meter and the Haskell meter and 0.22 foot for the small Price meter. (See fig. 16.)

(8) The small Price meter should be frequently rated, and it should be used with much care if accurate results are required.

(9) The six-tenths-depth method gives discharge from 2 to 6 per cent in excess of that by the weir, depending on the ratio of width to depth. (See fig. 17.)

(10) The integration method as a rule gives results in excess of those given by the weir, the difference increasing with the speed of the meter and decreasing as the velocity increases. (See fig. 17 and tables on pages 84 and 85.) By using special care in moving the meter at a slow speed and a uniform rate it may be possible to obtain better results by this method than those shown by these experiments. A device like Harlacher's (page 36) for giving the meter a uniform motion will increase the accuracy somewhat. We do not believe, however, that the little saving of time of this method over that by the mid-depth or the six-tenths-depth will warrant the use of any such device. The method is useful only as a rough check on one of the other methods.

(11) The thread of maximum velocity is at the surface for depths less that 2 feet and unobstructed flow at the lower end of the canal. For depths of 5 feet or more and discharge checked at the lower end of the canal this thread is from two-tenths to four-tenths depth below the surface, the mean for thirty-one experiments being thirty-one-hundredths depth. (See table on page 77.)

(12) The position of the thread of mean velocity varies from five-tenths depth for small depths to seventy-three-hundredths depth for the larger depths. For the thirty-one experiments by the ordinary method of series C and D it is sixty-four-hundredths depth below the surface. (See table on page 77.)

(13) The surface velocity is always greater than the bottom velocity with center of meter 0.25 foot above bottom. (See figs. 23 to 28.)

(14) The ratio of bottom velocity to mean velocity varies from 0.6 to 0.9, being 0.8 for the experiments of series A, 0.75 for series C, and 0.85 for series D. (See table on page 79.)

(15) The ratio of mean velocity to mid-depth velocity varies from 0.90 to 0.99, the mean of forty experiments being 0.95. (See table on page 79.)

(16) The average of the velocities 0.5 foot above the bottom and 0.5 foot below the surface is from −2.2 per cent to +30 per cent less than the mean velocity shown by the weir. (See table on page 83.)

(17) A small Price meter will revolve faster in moving water of a given velocity when held with a rigid rod than when held with a cable. (See table on page 89.) Hence the same rating table will not answer for both.

(18) The bottom velocity varies between so wide limits that it is not a desirable quantity to use in computing discharge; the mid-depth or the six-tenths-depth is better.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1899.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground water," by F. H. King, and one on "Theoretical investigation of the motion of ground waters," by C. S. Slichter.

1900.

Twentieth Annual Report of the United States Geological Survey, 1898–99, Part IV, Hydrography, 1900; octavo, 660 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell, and "Hydrography of Nicaragua," by A. P. Davis.

1901.

Twenty-first Annual Report of the United States Geological Survey, 1899–1900, Part IV, Hydrography, 1901; octavo, 768 pp.

Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton; and "The High Plains and their utilization," by W. D. Johnson.

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Other papers are in preparation. Provision has been made for printing these by the following clause in the sundry civil act for 1896–97:

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